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UTILIZATION OF FRUIT IN COMMERCIAL PRODUCTION OF FRUIT JUICES[1]

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INTRODUCTION

THE GREAT INCREASE in commercial production of fruit juices has provided a market for much off-size, offgrade, and otherwise unsalable fruit, and to this extent has improved the market for the better fruit. Present trends indicate that for some fruits not only the culls but also fruit of the better grades will be converted into juice. The fruit grower as well as the juice manufacturer is interested, therefore, in the increased utilization of fruits for juice. This publication has been prepared to furnish the basic principles involved in the commercial preparation and preservation of fruit juices, by use of which the manufacturer can improve the quality of his product. From this information the grower can more intelligently arrange for utilization of his surplus fruit and select those varieties of fruits which can be used to best advantage in making juice. Since the initial investment for a properly equipped juice plant is high, and the market a highly competitive one, small producers of limited means will find it a difficult and risky field to enter.

Practical directions are also given for the commercial and farm-scale preparation of fruit juices and fruit-juice beverages. The home preparation of fruit juices is described elsewhere.[4] The information presented here is based on investigations made by the staff of the Fruit Products Laboratory of the University of California, on the investigations of other laboratories, and on commercial experience.

[1] This circular supersedes Circular 313, *Fruit Juices and Fruit Juice Beverages*, by John H. Irish.

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[4] Cruess, W. V. Preparation of fruit juices in the home. California Agr. Ext. Cir. 65:1–15. 1932. Reprinted 1933.

TRENDS IN FRUIT-JUICE PRODUCTION

Fruit juices, such as pineapple and tomato, previously produced to a limited extent, have now largely displaced in extent of production such juices as apple and grape, which were formerly widely distributed. Not only has there been a change in the relative importance of the juices but there has also occurred a marked change in packaging. Cans have largely replaced bottles, and still juices have become more popular than the carbonated. The annual production of canned juices for which statistics are available is given in table 1. An estimate of the relative volumes of the various juices produced in 1935 is given in table 2.

TABLE 1

TOTAL UNITED STATES PRODUCTION OF JUICES IN ACTUAL CASES OF ALL SIZES

Year	Apple juice in glass	Grape juice in glass	Grapefruit juice in cans	Orange juice in cans	Pineapple juice in cans	Tomato juice	
						Cans	Glass
1929	———	———	205,000	———	———	185,000	———
1930	———	———	179,934	37,552	———	1,338,964	———
1931	———	———	416,683	99,209	———	3,476,244	———
1932	———	———	288,324	36,362	———	4,583,635	———
1933	———	———	728,691	110,597	700,000	4,170,794	433,259
1934	———	———	629,576	342,678	2,000,000	5,703,920	435,256
1935	1,250,000	1,000,000	2,675,586	1,107,299	2,500,000	8,170,640	967,872
1936	1,450,000	1,000,000	2,227,074	1,462,452	5,000,000	———	1,000,000

Source of data:
Anonymous. Products survey. 11. Canned and bottled fruit juices. West. Canner and Packer **28** (6): 17–18. 1936.

The expansion of the market for fruit juices is due in part to the effective advertising of the citrus industry which popularized the drinking of orange juice at breakfast. However, the improvement in the quality of the finished product and the perfecting of suitable can enamels have also had a great influence on the present development. The United States consumers are more juice-conscious today than ever before and are more receptive to new fruit juices. Thus, they have received favorably such juices as apricot and prune which have been marketed recently, although these juices were not favorably received by the trade when they were introduced several years ago.

A recent survey has shown that most of the fruit juices served in the home are used at breakfast, the next largest use being as a between-meals drink especially for children. The use of juice in fruit-juice beverages, such as punches and ades and in mixed drinks is least important in the home. However, certain prepared juices, such as lemon juice, are used

largely for mixed drinks and in bakery products. The common use of fruit juices at breakfast has resulted in the increased production of still and somewhat tart juices rather than of carbonated fruit-juice beverages so popular less than a decade ago.

TABLE 2

Production of Fruit Juice in 1935

Fruit	Total average United States supply, in tons	Tons used for juice purposes in the United States	Tons used for juice in the Pacific Coast states	Cases of juice produced in the United States	Cases of juice produced in the Pacific Coast states
Apples	3,517,000	33,000	3,300	1,250,000	125,000
Grapes	1,847,000	22,900	2,100	1,000,000	100,000
Grapefruit	681,440	107,500	3,800*	2,675,586	70,000*
Lemons	302,000	1,000	1,000	10,000	10,000
Oranges	2,123,560	35,428	27,428	1,107,299	817,232
Pineapples	268,000	100,000	100,000†	2,500,000	2,500,000†
Prunes	258,000‡	———	5,000§	———	———
Tomatoes	———	———	———	7,200,000	1,345,000
Others	———	7,000	6,750	400,000	300,000

* California and Arizona.
† Hawaii.
‡ Normal crop about 190,000 tons.
§ California.

Source of data:
Anonymous. Products survey 11. Canned and bottled fruit juices. West. Canner and Packer **28**(6):17–18. 1936.

GENERAL PRINCIPLES

The most important problem in the preparation and preservation of fruit juices is that of retaining in the finished product as much as possible of the pleasing qualities of the fresh juice. The methods of preparation should alter the original fresh-fruit aroma and flavor as little as possible. Any fruit juice is best when it is first pressed from the sound fresh fruit, and any treatment that may be given it thereafter usually injures its delicate flavor and aroma. The appearance of the juice can be improved, as by making it clearer, but the natural flavor cannot be improved upon. Second only to the retention of flavor and color is the retention of nutritive value. Fruit juices have been included in the diet, particularly of growing children, largely as a source of water-soluble vitamins (B and C) and obviously these should not be destroyed. The fruit acids, sugars, and the mineral salts present, which are also highly beneficial, are more stable than the vitamins and usually are not affected by the processing.

The nature of the fruit, the method of extracting the juice, as well as the method of preparing and preserving the juice, influence its quality. Not all species of fruits are suitable for juice and not all varieties of the juice fruits are equally desirable. The variety of the fruit used,

the locality and conditions under which it is grown, its maturity and condition when used, have a marked effect, not only on its initial flavor, but also on its keeping quality. The best juice can be made only when freshly picked, sound fruit, of a suitable variety, and at its optimum maturity, is used. Good juice cannot be made from moldy, decayed, or split fruit. Off-size, blemished, or sound fruit otherwise unsalable for table use may be used.

The structure and composition of the fruit determine the method that should be used for extracting the juice. Among the more important factors that are involved are: the nature of occurrence of the juice in the fruit, whether in localized areas or elements or uniformly distributed throughout the fruit; whether in easily ruptured juice cells or in cells surrounded by mucilaginous or gummylike substances; the presence of undesirable constituents such as bitter glucosides, astringent or bitter tannins, objectionable oils, and enzymes in localized tissues; the location of desirable constituents such as color pigments and flavoring substances; and the rigidity of the structures surrounding the juice tissues. In general, the juice in the whole fruit is contained within the cells or in juice sacs and does not come in contact with the various tissues that go to make up the remainder of the fruit structure. During the extraction of the juice, the various tissues are broken, and the juice is mixed with them and as a result may absorb the undesirable products these contain. Furthermore, fluid containing undesirable elements may be pressed out of the tissues surrounding the juice sacs. Therefore, the juice should be extracted by methods which result in the minimum of contamination with undesirable constituents present in the tissues surrounding the juice cells, or sacs.

Not only the method of extraction, but also the manner in which it is employed is important. It has long been known that exposure of citrus juices to air results in considerable changes in flavor and color, and recent experience has demonstrated the undesirability of exposing other and more stable fruit juices, as for example, apple and grape, to air either during extraction or subsequent handling. Avoidance of exposure to air, during both extraction and subsequent treatment, and the removal of the air present in the juice by holding it under high vacuum is necessary not only for the more complete retention of initial flavor, but also for the retention of those vitamins subject to destruction by oxidation, such as vitamin C. Contamination of the juices with metals, particularly iron and copper, absorbed during extraction, clearing, or processing, is to be avoided also. These metals not only give the juice an objectionable metallic flavor but also hasten oxidative changes and

may produce objectionable precipitates, such as iron tannates. Corrosion-resistant materials should be used for all equipment coming in contact with the juice during extraction and processing.

The clearing of fruit juices, either mechanically as by filtration, or chemically as by the use of fining agents, is another important factor in flavor retention. While the improvement in appearance by removal of the coarse particles of pulp and the seeds and other tissue fragments is desirable, complete clarification often adversely affects the flavor and color of the juice. It is well known that juices completely freed of suspended material are more stable. This fact, in addition to the wide use of glass containers for juices, was probably responsible for the former wide practice of filtering or clarification. However, much of the flavor and the color of fruit juices, such as the orange and tomato, is contained in the suspended material, the removal of which would detract from the appearance and flavor of the product. To market citrus juices in the cloudy condition has long been customary, and with the advent of suitably lined cans this practice has extended to the other major fruit juices. The amount of pulp to be left in the juice, however, depends, on the one hand, on the content of enzymes and other undesirable constituents, and on the other hand, on the presence of coloring and flavoring bodies. It is not easy to strike a proper balance which would result in the retention of the minimum of those agencies responsible for off-flavors and losses in color and the maximum of the desirable color and flavor-bearing bodies.

Finally, the activity of the agencies responsible for the spoiling of the juice, particularly the microörganisms and the enzymes, should be inhibited with the minimum effect on flavor. At present, the destruction of these agencies by heat has proved to be more practical than the storage of the juices under conditions unfavorable to their activity. Since fruit juices, especially citrus juices, develop undesirable cooked flavors when they are heated at the usual pasteurizing temperatures of about 175° Fahrenheit for the times necessary to destroy the microörganisms and because higher temperatures or much longer times are needed to destroy the enzymes, pasteurization at temperatures of about 200° F for short periods of time is usually employed.

The more important steps in the process of fruit-juice manufacture are: (1) the selection and preparation of fruit, (2) the extraction of the juice, (3) improving the appearance of the juice, (4) deaeration, and (5) preservation.

SELECTION AND PREPARATION OF THE FRUIT

Freshly picked, mature fruits form the chief raw material. However, dried fruits, particularly prunes, are also used. Not all fruits can be used, either because of the difficulties in preparing juice from them, or because their juice lacks flavor and color or is unstable and difficult to preserve. Apples, berries, grapes, pineapples, tomatoes, and the citrus fruits are at present the more important juice fruits. However, pomegranates and passion fruit have been used, and pleasing beverages can be made from crushed apricots and peaches. The varietal and maturity factors involved for each fruit differ somewhat.

Apples.—Apples of sprightly to acid flavor are best, provided they are ripe and possess a full apple flavor. Of the varieties grown commercially in California, the Yellow Newtown has been found satisfactory. The Yellow Bellflower is of poor flavor; the Gravenstein is of fair quality for juice but not so good as the Yellow Newtown; the Jonathan, Winesap, and other varieties of sprightly flavor are excellent, but scarce in California. Varieties of very low acid content, such as the Gano, are of little value and produce juices which are difficult to sterilize. Varieties which may have sufficient acid but are of poor flavor are likewise not successful. To this class would belong the Yellow Bellflower and the Ben Davis.

The apples should be mature enough to possess their full flavor, but should not be overripe, because of the decrease in acidity after maturity is reached and because juice from overripe fruit is "gummy" and very difficult to filter. An apple is in ideal condition for making into cider when about midway between market-ripe and dessert-ripe.

Blending or mixing the juice of two or more varieties is often necessary in the making of first-quality apple juice. To be acceptable to the user, a fruit beverage in addition to having the aroma and flavor characteristic of the fruit from which it is made must be properly balanced in sugar, tannin, and acid content. If the tannin content of a juice is high in relation to its sugar and acid, as in many crab apples, the juices will be harsh and astringent; if the acidity is high, as in most varieties picked in the market-ripe condition, the juice will be sour; while if the sugar content is high in relation to the other constituents, as in the Gano, McIntosh, Grimes Golden, and Delicious varieties, the juice will be more or less insipid and lacking in sprightliness. Moreover, apple varieties differ greatly in the amount of characteristic apple flavor possessed by their juices. The classification by Caldwell[5] of varieties of apples for cider as shown in table 3 will aid in making the proper blend.

[5] For further details consult: Caldwell, Joseph S. Farm manufacture of unfermented apple juice. U. S. Dept. Agr. Farmers' Bul. 1264:1–56. 1922.

TABLE 3

Classification of Apples for Use in Making Cider

Group	Characteristics	Typical varieties	Blending
Group 1: Sweet-subacid	Dessert apples free from astringency and neither distinctly sour nor markedly sweet; when picked at proper stage of maturity juice is sweet and of good flavor but is somewhat lacking in acidity	Yellow Newtown Esopus Spitzenburg McIntosh Rome Beauty Grimes Golden Baldwin	Form basic stock; may be improved by blending with varieties in groups 2 and 4
Group 2: Mildly acid to slightly tart	Popular dessert varieties which when pressed at the proper stage of maturity will yield an almost suitably balanced juice; they have a degree of acidity and suggestion of astringency which give proper balance to their sugar content	Yellow Newtown Winesap Jonathan Stayman Winesap Arkansas Black Rhode Island Greening Gravenstein Wagener	Any one of these varieties may be used to make a good juice; or to improve juices from group 1 varieties by adding flavor and acidity when blended in the proportion of 5 to 20 per cent
Group 3: Aromatic	Juice not well balanced in sugar and acid, but apples possess exceptional fragrance and aroma and agreeable flavor which are carried over into the cider	Delicious Golden Delicious White Pearmain Winter Banana Gravenstein	Improve basic stock when added in the proportion of 5 to 10 per cent. Give cider a distinctive flavor and aroma
Group 4: Astringent	Because of their high tannin content add to the pungency and tang of basic stock; juice high in tannin and acid, as to be almost harshly astringent	Crab apples	From 3 to 5 per cent of crab-apple juice which may be so highly astringent and highly acid as to be unpalatable will give an added tang and zest to finest juice
Group 5: Neutral	Mediocre character; lack dessert quality or high flavor; juice is characterless and devoid of distinctive flavor even when fairly well balanced in sugar and acid content	Gano Ben Davis Yellow Bellflower Alexander	May be added to good basic stock to not over 20 per cent to give bulk; balance them by an increased addition of varieties of the acid or aromatic group

Source of data:

Caldwell, J. S. Farm manufacture of unfermented apple juice. U. S. Dept. Agr. Farmers' Bul. 1264:12–14. 1922.

Berries.—Logan (Loganberry) juice is still the most popular berry juice. It was at one time produced on a large scale in Oregon and after a lapse of a few years is now being reintroduced. The juice is of deep-red color, very rich flavor, and high acidity. Thoroughly ripe fruit gives the best juice, that from underripe berries being light in color and excessively tart and astringent in flavor. Blackberries and raspberries lack the acidity necessary to a desirable product, and strawberries yield a

juice much too unstable in color and flavor to be desirable. The newer varieties of berries, particularly Young (Youngberry) and Boysen (Boysenberry) blackberries produce attractively colored juices of very pleasing flavor. Although Young blackberry juice is produced to but a limited extent, it has, in our opinion, marked commercial possibilities.

Citrus Fruits.—Of the more common citrus fruits, grapefruit yields the most stable juice, and largely because of this fact grapefruit juice is more widely produced and distributed in the preserved form than are the other citrus juices. It is produced principally in Florida where the Duncan variety is preferred; it is also made in Puerto Rico, Arizona, and Texas.

Because orange juice does not retain its flavor so well when preserved by pasteurization, and because of the difficulties in the distribution of the juice preserved by freezing, freshly extracted juice prepared for immediate consumption is more widely distributed than is the preserved juice. Canned orange juice, however, has found favor in spite of the fact that some of the fresh flavor is lost in processing and storage. Moreover, the production of canned orange juice is steadily increasing.

Lemon juice and lime juice are much less stable and only a small quantity of lemon juice is canned. At the present time the product is distributed chiefly to cosmeticians, bakeries, and bars. The character of the oil present in the peel, particularly its high content of citral, the difficulty of extracting the juice without contaminating it with peel oil, and the high acidity of the juice, which favors the decomposition and staling of the oil, are the more important reasons for the unstability of lemon juice.

Tangerine and tangelo fruits produce a highly colored, well flavored, stable juice which should prove popular.

Variety and maturity are extremely important in the selection of citrus fruits for juice purposes. Citrus fruit, in contrast with other juice fruits, are borne on evergreen trees and consequently are slow to reach maturity. While it is true that during development all fruits continually change in composition, the rate of change in citrus is markedly slower than in the deciduous fruits. In the latter fruits, maturation changes occur at a very rapid rate and they also cause rapid decline in quality once maturity is reached. Citrus fruit, on the other hand, approaches maturity with gradual change in composition; a period of several months is often required for the fruit to pass through the stages immature, ripe, optimum maturity, and overmature. The juice extracted from fruit at its optimum stage of maturity is superior in flavor and keeping quality to that extracted from immature or overmature fruit.

The fruit picked early in the season, although ripe according to federal standards, gives a juice that rapidly turns bitter and becomes objectionably stale. The overmature fruit yields a juice that is flat and watery in flavor, although it does not turn bitter. Since there is no definite correlation between the sugar-acid ratio, a test commonly used as guide to maturity and keeping quality of the juice, it is difficult to set an absolute standard of maturity of fruit to be used for juice purposes. Although Valencia oranges are marketed in California from April to November, they are at their best for juice purposes only for a period of some 4 to 6 weeks.

In California the Valencia variety yields a more palatable juice of better keeping quality than the Washington Navel orange. The latter is not suitable for producing juice extracted by burring or by other commercial methods. Bitterness develops in the extracted Navel juice over a much longer portion of the growing season than it does in Valencia juice. The midseason varieties such as Mediterranean Sweet, St. Michael, and certain seedlings yield juice as good as that of the Valencia or even better. The locality where the fruit is grown also influences its desirability for juice; the coast counties, particularly Orange County, produce a fruit that is considered superior by commercial juice producers.

The size of the fruit as well as its maturity affects the flavor of the juice. Table 4 gives the composition of Choice Valencia oranges of different sizes picked at the same time from the same grove. Two-dozen fruits of each size were analyzed; the juice was extracted by burring the halved fruit and the extracted juices were strained through a screen perforated with 80 1-millimeter holes per square inch. The results substantiated the common opinion that small fruits are sweeter.

Grapes.—At present the most popular juices are those made from the Concord and other closely related eastern (that is, labrusca) varieties. In California the Pierce Isabella is used as a substitute for the Concord, since it combines in a single variety high color, high acid, and the favored "foxy" flavor of the labrusca-grape varieties. It may be grown most successfully in the coast counties.

A red juice is commonly preferred, and the more intense the color the better. High acidity, that is, a tart flavor, is necessary in a successful product. In addition, the juice must have a distinctive and pleasing flavor. If the product is to become popular, this flavor must be very pronounced.

No single variety among those commonly grown in California (vinifera varieties) possesses all of the desired qualities. The Muscat of Alexandria has a strong flavor but is white in color and not very high in acid.

When blended with suitable varieties of red wine-grape juices a very pleasing product, which compares favorably with Concord juice in color, acid, and flavor, can be made. It is believed that such a juice can become a strong competitor of eastern juices. Among the red wine grapes certain varieties, such as Barbera, Valdepeñas, St. Macaire, and Refosco (Crabbe's Black Burgundy), give better juices for blending with the

TABLE 4

VARIATION IN AMOUNT AND COMPOSITION OF ORANGE JUICE WITH SIZE OF FRUIT

Size*	Per cent by weight			Composition of juice				Weight per orange, grams	Volume of juice per orange, cc	Gallons of juice per box
	Peel	Pulp	Juice	Specific gravity 20/20	Balling degree	Acidity†	Ratio‡			
100	45.2	8.4	46.4	1.0414	10.35	0.857	12.1	308	137.5	3.6
126	43.2	7.2	49.6	1.0425	10.60	0.869	12.2	280	133.0	4.4
150	41.9	7.1	51.0	1.0479	11.90	0.892	13.35	230	111.5	4.4
176	43.2	6.7	50.1	1.0510	12.65	0.893	14.15	201	95.8	4.4
200	40.6	8.3	51.1	1.0527	13.05	0.908	14.3	178	86.4	4.6
216	43.2	6.5	50.3	1.0551	13.60	0.898	15.3	157	75.0	4.3
252	44.6	7.0	48.4	1.0572	14.10	0.965	14.65	143	65.7	4.4
288	42.1	8.2	49.7	1.0576	14.20	0.972	14.6	116	59.4	4.5
344	40.0	9.0	51.0	1.0591	14.55	1.012	14.35	103	49.6	4.5

* Number of fruits per standard box.

† Total titratable acidity expressed as per cent anhydrous citric acid.

‡ Ratio of soluble solids as sugars to acidity.

Source of data: Compiled by the authors.

Muscat than do the commoner varieties, such as Petite Sirah, Zinfandel, Alicante Bouschet, Carignane, and others, but these latter varieties may also be used successfully.

For the production of juices of delicate flavor, which will appeal to connoisseurs of fine wines, varieties such as Semillon, Franken Riesling, and Sauvignon Vert should be blended with acid varieties, such as Burger and Golden Chasselas.

The composition of the finished juice is governed by the locality in which the grapes are grown and the time of picking. The many varieties of grapes in California are grown under widely different conditions of soil and climate. The effect of these factors on their physiology, morphology, and chemical composition has been the object of a great deal of study both in Europe and in the United States for many years. The chemical composition of the grapes of any one particular variety has been shown to be dependent upon the soil type and climatic conditions under which the grapes are grown. Changes in soil type result in chemical changes in the ash constituents of the juice and can be considered as

of only minor concern to the grape-juice manufacturer. Climatic variations on the other hand affect the sugar-acid ratio, the color, and the tannin content of the juice; all of which are factors directly influencing the quality of the juice. To obtain the highest quality of juice, the manufacturer should therefore purchase his grapes only from those sections known to be best adapted for any particular variety; for example Muscat grapes from the interior valleys and Zinfandel from the coastal counties.

Maturity is also a factor influencing the chemical composition of the grape. Eastern varieties should be gathered at about 17° to 18° Balling as indicated by the Balling hydrometer. This concentration is easily reached in California, but is difficult to attain in eastern grape-growing regions. Muscat, Semillon, and other flavor grapes must reach the stage of maturity at which their flavor is well developed. This is 22° to 23° Balling. The acid grapes to be blended with the flavor grapes should have a good color but still be very sour; that is, about 18° Balling. With Zinfandel grapes, in order to obtain both acid and color, the first crop will have to be gathered at 20° Balling for color and at the same time enough of the second crop gathered to impart a very tart flavor. Ordinarily the color and the acid varieties will have to be gathered several weeks before the flavor varieties have ripened sufficiently and their juice preserved until they can be blended with the flavor juice.

Passion Fruit.—The best commercial species, *Passiflora edulis,* originated in southern Brazil, is well established in Australia, and is grown to a limited extent in southern California where it is marketed through the Passion Fruit Coöperative Association. The fruit is about the size of a large plum, the color changing from green to a dark glistening purple, almost black, as it matures. Each fruit contains, on an average, 150 speckled black seeds surrounded by a gelatinous orange-colored acid pulp, enclosed in a shell about ⅛ inch thick. After harvesting, the shell tends to dry out and shrivel somewhat, but the delightful flavor and odor of the pulp is unaffected. The pulp is widely used in Australia, and its juice has been marketed to a limited extent in California, particularly for use in ices and sherbets. The strong flavor of the juice may prove popular. Ordinarily the juice is too tart to use unmodified and is usually sweetened and diluted.

Pomegranates.—The brilliant purplish-red color of the juice and its pleasing flavor make it useful for blending with other fruit juices. Ordinarily it is too tart, and the flavor is not retained very satisfactorily unless the juice is sweetened before bottling or canning. Splitting of the fruit on the tree is a good indication of maturity for the Wonderful

variety of pomegranate. This is a natural characteristic of the fruit and occurs extensively during the ripening period. When splitting occurs the fruit has usually reached the optimum condition for juice production since it is then thoroughly ripe, is high in sugar content, rich in flavor, and the juice is dark red in color.

Tomatoes.—Tomato juice, like grapefruit juice, was first produced as a means of utilizing the waste products from tomato-canning operations. Today, however, most of it is made from the whole fruit. The best juice

TABLE 5

COMPOSITION AND COLOR OF COMMERCIAL TOMATO JUICES

Sample	Total solids, per cent	Total soluble solids, per cent	Total acid as citric, per cent	Salt, per cent	Color index			
					Hue	Chroma	Value	Rating
Western United States								
Average (62 samples)	6.74	6.19	0.388	0.555	6.62	10.38	2.96	9.28
Maximum	8.31	7.71	0.563	1.071	5.32	11.85	2.52	6.47
Minimum	5.28	4.85	0.233	0.022	7.76	8.49	3.29	11.94
Eastern United States								
Average (27 samples)	6.16	5.68	0.383	0.687	6.98	9.92	3.02	10.09
Maximum	8.71	8.00	0.496	1.059	6.05	11.29	2.44	8.33
Minimum	4.72	4.12	0.269	0.000	8.15	7.21	3.32	12.38

Source of data:
Mitchell, June S. Comparative composition and color of commercial tomato juice. Jour. Assoc. Off. Agr. Chem. **18**: 128-35. 1935.

can be made only from fully mature tomatoes rich in color and possessing the proper sugar and acid content. Not all canning varieties are suitable for juice. Small red fruits, fully colored and free from all evidence of green are necessary to produce juice of pleasing color and flavor. The vitamin content of the canned juice depends on the maturity of the tomato and the methods used in extracting and processing the juice. At present there is too great a variation in the composition, flavor, and vitamin content of the canned juice (table 5). This is due in part to differences in origin, for tomato juice, unlike other fruit juices of commercial importance, is canned in large quantities in widely separated parts of the United States. Another factor is the differences in quality of fruit used and also variations in process. Color is probably the best index of maturity.

Dried or Fleshy Fruits.—"Prune juice," a product prepared by extracting water-soluble solids from off-size or offgrade dried prunes, has

proved to be popular because of its dietary qualities, particularly its high content of vitamin B, and its laxative qualities. "Apricot juice," prepared by the addition of light sirup to the crushed ripe fruit, is another product that is promising. Fully ripe Blenheim or Royal apricots are used.

Storage of Fruit.—The freshly picked fruit yields a better-flavored juice than that extracted from fruit held in storage. The storage of fruit before extraction either at room temperature or under refrigeration results in juice of poorer flavor and keeping quality. However, the length of the storage period necessary to produce marked changes in the character of the juice varies with the respiratory activity of the fruit and with storage conditions. Thus, ripe tomatoes do not store well at all, whereas apples have been kept in cold storage satisfactorily for several months. The maximum storage time advisable for Riverside Valencia oranges was found to be 2 weeks at 70°F and 4 at 33°F.

Washing.—Fruit often arrives at the factory dusty and contaminated with other foreign substances. Washing will not only improve the flavor and appearance of the product but will also facilitate preservation by removing mold spores, yeast and other microörganisms, dust, smut, or other foreign matter adhering to the skin. The rotary tomato washer is an effective washing device for fruits that will stand rough treatment. Citrus-fruit washers such as are used in fresh-fruit packing-houses may be used in juice plants, although these are generally modified to suit the needs of the individual fruits. Usually the citrus fruit is sterilized before use by rinsing in a hypochlorite bath maintained at a strength of 100 p.p.m. of chlorine. Berries and other soft fruit which will not stand rough treatment must either be rinsed by hand or washed under a gentle spray of water.

Apples sprayed with lead arsenate for controlling the codling moth bear residues at harvest that may be injurious to health; excessive amounts must be removed before the fruit is offered for sale. Recent federal regulations have established the tolerance for lead at 0.018 gram per pound and for arsenic 0.01 grain as arsenic trioxide. Lead arsenate cannot be removed sufficiently with water to meet the requirements of the law. Apples to be used for cider were formerly not treated to remove spray residue because of the relative insolubility of the residues in the juice. Today, however, the practice is to wash the apples before use in a water bath containing chemicals which dissolve the spray residue. Hydrochloric acid is generally preferred to sodium silicate for treating cider apples. The apples are agitated in a solution of 1.5 per cent hydrochloric acid prepared by adding 5 gallons of the commercial acid to

100 gallons of water. The bath should be maintained at 100° F. After washing with acid the apples should be rinsed in fresh water. Several types of washing devices and various wetting agents have been developed[6] (fig. 1).

Sorting and Grading.—Grove-run or packing-house cull fruit must be sorted to remove decayed, moldy, and otherwise unfit fruit before it is used for juice. Only a very small percentage of moldy, rotted, or overripe fruit has a deleterious effect upon the flavor and quality of the fruit juice. This is particularly true of oranges and tomatoes.

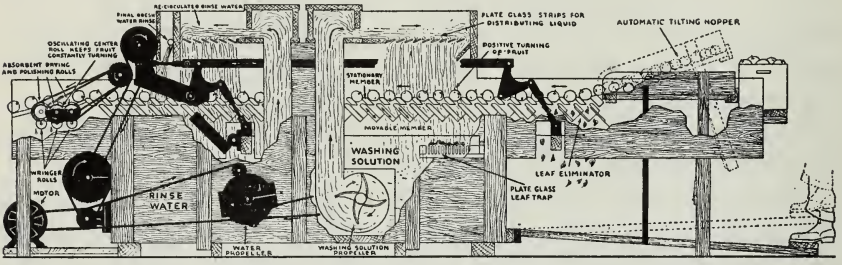

Fig. 1.—Diagrammatic sketch of a chemical fruit washer.

Broad, heavy-woven endless cotton or rubber belts which carry the fruit slowly past the sorters are often used in canneries and evaporators. They may be used to advantage, especially with apples, in sorting fruit for juice manufacture. Belts made of metal cloth, similar to ordinary metal door matting, are very satisfactory because they may be easily washed and may be fitted with sprays at one end for washing the sorted fruit. Such equipment is obtainable from any cannery-supply company.

To facilitate the operation of several types of mechanical juice extractors, citrus fruit must be graded for size. Usually three size grades are sufficient. The more recent equipment is built to function with fruit of a wide variety of sizes.

JUICE EXTRACTION

In general, juice is extracted from the fresh fruit by a process of crushing and pressing modified to suit the special conditions presented by each fruit. The particular method of extraction to be used for producing the best juice is determined by the structure and composition of the fruit.

Apples.—Apple tissue is firm and tough and the cells have heavy walls. The juice is largely cell sap. The entire fruit is fairly uniform

[6] For the more recent information see the articles on spray-residue removal in the "Selected List of References."

in structure, and the cell walls, the skin, and other tissues surrounding the juice in the cells do not contain substances which would markedly impair the flavor of the juice. Consequently, the fruit may be crushed, and the crushing must be thorough and the pressing severe to obtain a high yield of juice. Crushing too fine, however, causes the pulp to be too soft to press without danger of breaking the press cloths. Pieces ranging in size from ⅛ to ½ inch in diameter are satisfactory. The crusher can be set to grind to any desired degree of fineness.

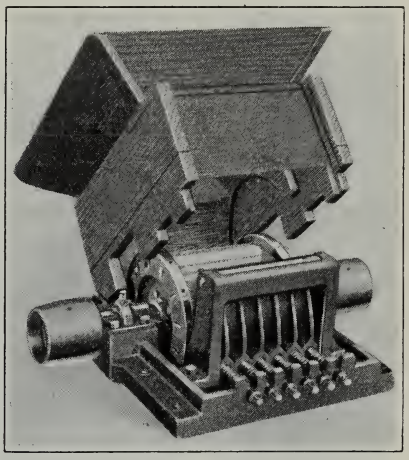

Fig. 2.—An apple grater suitable also for crushing certain soft fruit.

One type of crusher commonly used for apples, known as the "apple grater," consists of a cylinder, on the surface of which are fixed short knives working against a corrugated plate (fig. 2). In addition there is sometimes a set of concave or upright knives, against which the cylinder revolves. The fruit is grated or crushed between the plate or concave knives and the cylinder. The upright knives or the corrugated plate are fixed to strong springs in order that the crusher will have flexibility and not be broken by pieces of wood or stone which may accidentally fall into the crusher. The crusher is usually mounted on the press.

A second type of pulper that has come into rather general use during recent years is known as the "hammer-type pulper." It consists of a strong wood frame supporting a revolving shaft with heavy hammers, or beaters, and a heavy perforated half-round metal screen through which the pomace is forced when reduced to the proper consistency. The hammers are lengths of steel bars and are arranged on the shaft in the form of a spiral cylinder which barely clears the metal screen. Fruit entering the pulper is struck by the hammers with such terrific force that every particle is reduced to pulp. The screen below the hammers eliminates the possibility of any piece's passing through the machine until pulped. The fineness of the pulp, or pomace, is regulated by the speed of the machine and the best results are obtained when the pulper is operated at from 2,500 to 3,000 r.p.m. It is largely replacing the apple grater formerly in universal use because careful tests have proved that larger yields of juice can be obtained through its use.

After opening the juice cells by crushing, the resulting pulp is pressed to expel the juice. The press most commonly used for apples is the rack-and-cloth press such as is shown in figure 3. In this press the crushed fruit is built up in layers in heavy, coarse-weave press cloths between racks made of wooden slats. Pressure is ordinarily applied by means of a ram operated by a hydraulic pump, although other types of pressure units are also used. A pressure of at least 500 pounds per square

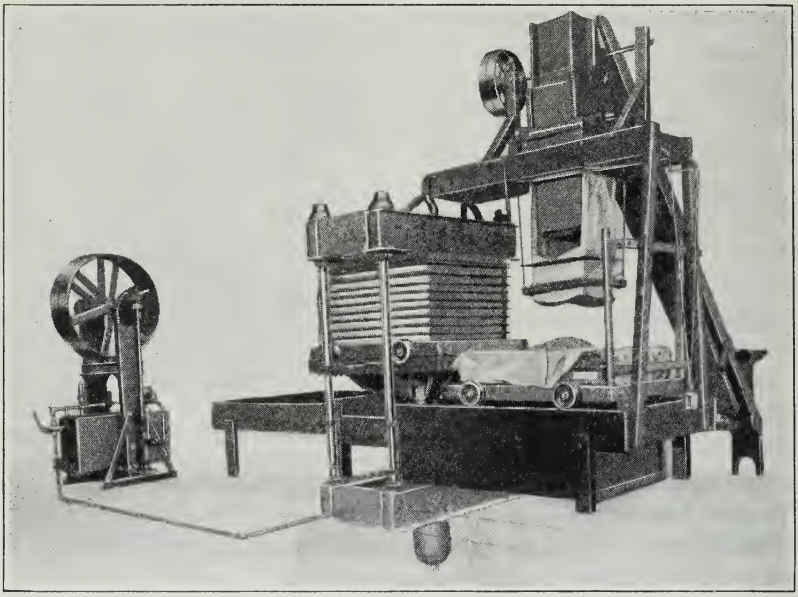

Fig. 3.—Large-sized apple grater and rack-and-cloth press.

inch is necessary for the best results. The press cake will yield more juice if broken and pressed a second time; this juice is of poorer quality and should be used for vinegar manufacture.

For small-scale production a basket press may be used. But this yields less juice than the rack-and-cloth press and usually a more cloudy juice. Continuous screw presses are not used because the resulting juice is too cloudy and hard to clear.

Berries.—Berries, with the exception of strawberries, are similar in structure, consisting of seeds about which is a layer of mucilaginous juice cells. The color is not uniformly distributed throughout the cell sap but is localized in the walls and in the chromoplasts. The juice is best extracted by a combination of crushing, heating, and pressing. Heating is necessary to coagulate or liquefy the gummy substances surrounding

the juice cells and cause the juice to run freely. It greatly facilitates pressing, and also extracts and fixes the color. Freezing accomplishes the same results as heating, and excellent berry juices can be prepared from fruit preserved in this manner.

The unheated berry pulp is very slimy in character and difficult to press, particularly in a rack-and-cloth press. As pressure is increased the fruit often slips out of the forms. Usually the berries may be suf-

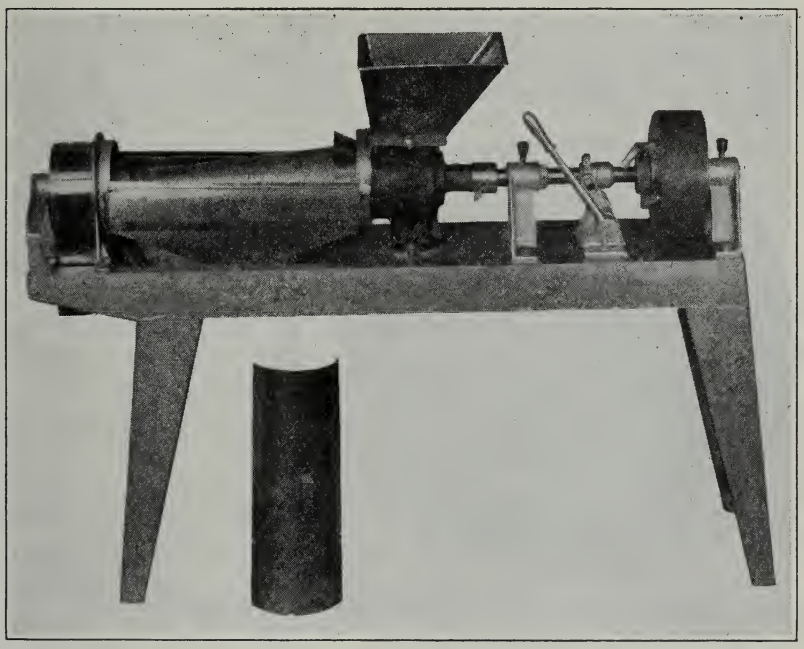

Fig. 4.—Conical screw expeller press.

ficiently well crushed by stirring with a paddle during heating. However, if they are too green or hard they may be crushed in an apple grater or in a grape crusher. The crushed fruit should be heated in steam-jacketed kettles, preferably of noncorrodable metal, with constant stirring to about 140°F and pressed at once. Long continued heating extracts tannin and other disagreeably flavored substances from the seeds. The rack-and-cloth press should be used for pressing.

A continuous screw expeller press, so constructed as to extract the maximum of juice with the minimum crushing of seeds and other tissues, may be used (fig. 4). Presses of this type generally consist of a hopper into which the fruit is fed, a screw conveyer then leading the fruit to the press proper. This consists usually of a conical screw revolving in a

perforated screen housing or a solid housing with a screen on the bottom. As the fruit mass progresses forward it is subjected to increasing pressure caused by the gradually decreased clearance between the screw and the housing and by the decrease in the distance between the threads of the helical screw. The pulp is expelled at the end of the press. Because the fruit tissue is usually excessively macerated, the resulting juice is very pulpy. The juice extracted in the fore part of the press by light pressure is clear but the yield is low.

Citrus Fruit.—The juice is present in small multicellular, spindle, or club-shaped juice sacs (fig. 5) which completely fill the segments or carpels of the fruit that are distributed about the soft, pithy core. Each

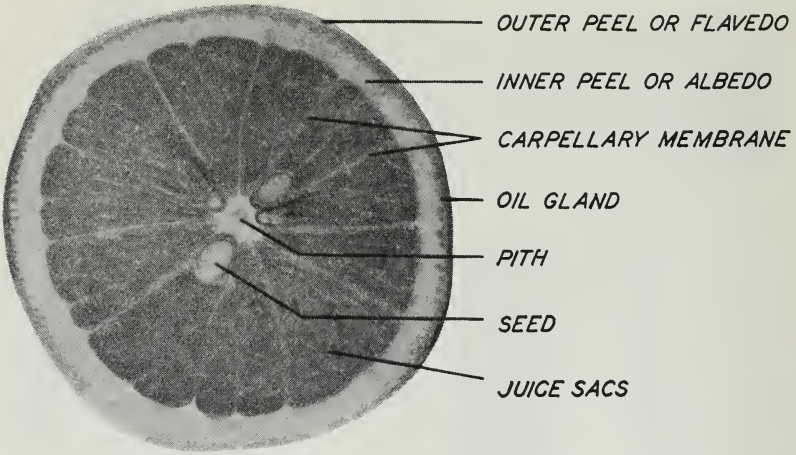

Fig. 5.—Section of the Valencia orange, showing structure.

segment is surrounded by a carpellary membrane. Closely adherent to the outer carpellary membrane are the vascular elements. Surrounding the segments is the rind, or peel, consisting of an inner, white, spongy portion, the albedo, and an outer colored portion, the flavedo. The inner portion of the flavedo contains the oil glands; the peel oil being present in balloon-shaped cells which are more or less easily broken. Substances responsible for the development of bitterness in the juice are located chiefly in the carpellary membranes, the vascular bundles, and the inner peel. The seeds also contain intensely bitter principles. Pectic substances and pectic enzymes are present largely in the inner peel. The oxidizing enzyme, peroxidase, is also largely present in the vascular elements and in the inner peel. The citrus oil present in the rind consists largely of terpenes such as limonene and of citral to which its flavor is largely due. Oxidization of the terpenes and decomposition of certain

other constituents of the oil in the presence of air, acid, and water, is probably responsible for the terpene flavor of the juice containing oil from the peel.

Probably the ideal method for the extraction of the juice would be that in which it is extracted without coming into contact with tissues other than the juice sacs. Unfortunately, no mechanical means for accomplishing this under practical conditions is available at present. The methods of extraction commercially used now are of three general types.

In one method, the fruit is completely peeled, and the juice is extracted in a continuous screw expeller press. Certain manufacturers claim to have perfected a type of press which avoids the introduction of the so-called "rag juice," that is, juice extracted from the carpellary membranes and pith. It is difficult to peel the fruit completely and to make such a system of extraction entirely automatic. Furthermore, in some types of presses the pulp is unduly macerated and ground with the juice.

In another method, the whole fruit is cut in half and the juice is extracted by pressure either in a plunger type of press, on a cylinder, or other graduated pressure device. In the plunger-type press the juice is extracted from halved fruit held in an inverted cup by pressing it against a metal form having the same shape as the cup. The clearance between the form and the cup is adjusted to a little more than the thickness of the peel to avoid pressing the peel. In the cylinder type, the halved fruit is opened and pressed against a drum, care being taken to remove the oil pressed from the peel. Other pressure devices may be used with the cut, and preferably peeled, fruit.

In the most commonly used method, the whole fruit is cut in half, preferably at right angles to the axis of growth, and the juice is extracted by pressing the halved fruit against a revolving conical ribbed or grooved extractor, or burr (fig. 6). A combination of pressing and tearing is used. Extraction by burring, or reaming, is unsatisfactory because it incorporates appreciable amounts of air, oil, and undesirable tissue into the product. The higher the speed at which the burr revolves the greater is the tearing and the less is the pressure. This results in a lower contamination of the juice with oil from the peel but more aeration and more contamination with other tissues. The reverse is true at low speeds. By properly adjusting the speed and the shape of the reamer, optimum conditions may be realized. This general method is more amenable to mechanical operation and several automatic extractors of this type are available at present.

The practice of crushing and pressing the whole fruit in an expeller

press, commonly used in by-products plants for the recovery of oil, citric acid, and pectin, is not desirable even when the juice is centrifuged to remove the oil. The centrifuged press juice is of poor keeping quality.

Several specially constructed citrus-juice presses are in use in southern California. In one type the whole fruit, after the outer oil cells are

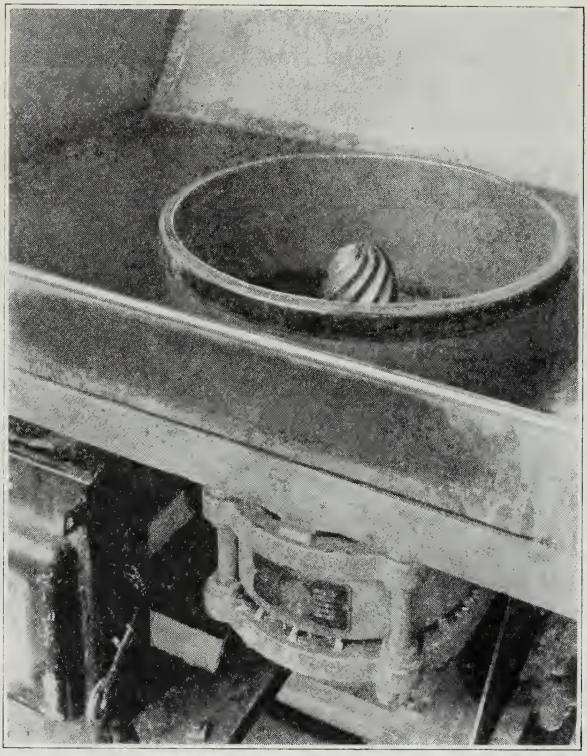

Fig. 6.—A reaming, or burring, unit for extracting orange juice.

buffed off mechanically, is pressed in a specially devised roller press. In another the fruit is halved, each half is pressed against a grill, and the pulp and juice are cut away from the bottom of the grill by mechanical knives; the pulp is then pressed to liberate all liquid.

Grapes.—The juice of grapes occurs in a gelatinous mass surrounding the seeds, if present, and is enclosed in a more or less firm skin. The berries are attached by small cap stems to larger stems forming the bunch. The stems and seeds contain much tannin and some bitter principles. In the red or black juice grapes the pigment is largely concentrated in the skins in a form that is soluble with difficulty in water or juice, and

heating is necessary to cause the color to flow freely into the juice. White juice grapes, on the other hand, should not be heated because the resulting juice is too cloudy and of unpleasant flavor.

For grapes, the usual crusher consists of two corrugated, or fluted, metal rollers which revolve close together and toward each other, carrying downward between them and crushing the grapes that are fed

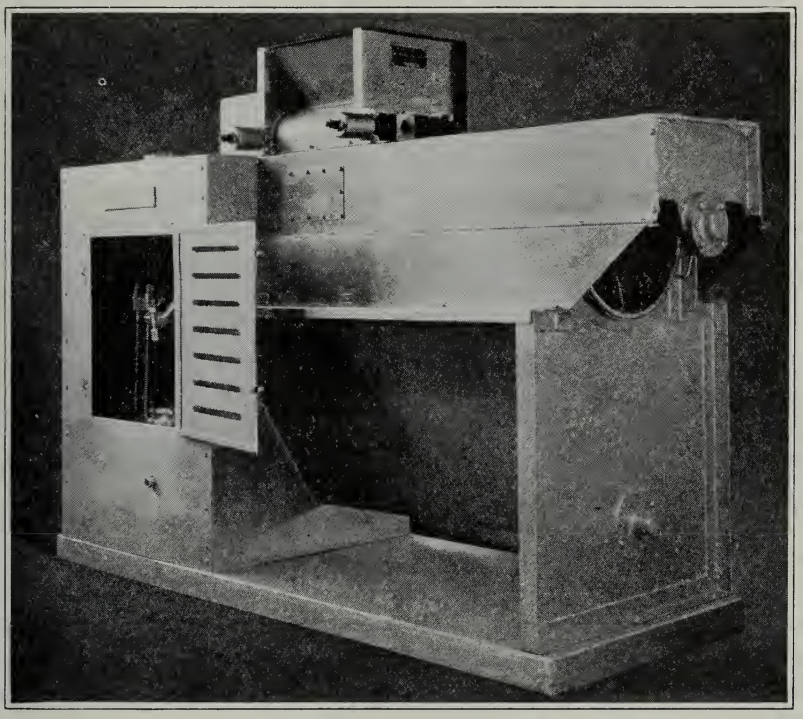

Fig. 7.—Modern-type continuous grape crusher, stemmer, and must pump unit.

into a hopper above. Connected with the crusher is a stemmer consisting of a horizontal metal cylinder with perforated bottom, through which the grapes are forced by revolving paddles (fig. 7). The stems cannot pass through these openings and are thrown out at the end of the stemmer.

Grapes for white juice should not be stemmed because the stems aid in pressing by giving rigidity to the mass and forming channels for the free passage of the juice from the central portion of the mass to the outside. Grapes for red juice should be stemmed because heating the juice later to extract the color will leach from the stems an astringent principle of disagreeable flavor. Although the rack-and-cloth press will give

a higher yield and a clearer juice than will the basket press, the latter is used to a large extent in California. The rack-and-cloth press is used in eastern grape-juice factories.

In basket presses the cloths and racks are not used. The crushed fruit is held in a strongly reinforced wooden basket of cylindrical shape, which rests on the press floor. The basket is movable. Pressure is applied by a lever and screw in small presses and by hydraulic pressure in the larger presses.

There are two methods in use for extraction of color from red grapes. The process most commonly used consists in heating the mixed skins and juice in a large double-jacketed steam-heated aluminum kettle to 160°F for a few minutes. The grapes are then pressed immediately while hot.

The other method consists in first lightly pressing the crushed, stemmed grapes to obtain one-half or two-thirds of the juice. The partially pressed skins and seeds are thrown into a clean wooden vat. The juice is heated in a bulk pasteurizer, to about 140°F, and is then mixed with the skins and seeds and allowed to stand until sufficient color is extracted. This will be 4 to 8 hours. The skins and juice should be frequently stirred to hasten color extraction. After that, the grapes may be pressed. Heating destroys the slimy character of the crushed red grapes and thus facilitates pressing so that the presence of the stems is not necessary.

The second method described above for color extraction has given the better results because overheating is avoided. High temperatures (150° to 180°F) of mixed juice and skins cause the juice to develop a harsh flavor, probably because of materials extracted from the seeds. Temperatures of 130° to 140°F for mixed skins and juice have been found to give the best flavor and at the same time permit satisfactory extraction of color.

Passion Fruit.—The pulp containing the seeds can be easily removed from the half fruits by burring, but the separation of the mucilaginous juice from the seeds requires a certain amount of rubbing as well as pressing. An extractor of the continuous conical screw expeller type or a tomato cyclone type is suitable. W. E. Sutton of the United States Department of Agriculture Laboratory of Fruit and Vegetable Chemistry has developed a passion-fruit juice extractor based on the paddle cyclone principle.

Pomegranates.—The rag and peel of the pomegranate contain so much tannin that juice from these portions of the fruit is too puckery to be drinkable. The desirable juice is in the arils, or berrylike fruit bodies (fig. 8). The problem is to separate these from the peel and rag.

It has been found that the smallest amount of tannin in the juice and the largest yield of juice is obtained when the whole fruit is placed in a rack-and-cloth press or basket-type press, and pressed without previous crushing. The less the fruit is macerated before pressing the lower is the astringency of the resulting juice. A slight astringency is desirable for it imparts a slight puckeriness which is appreciated by most consumers.

A continuous feed and discharge type of press for pomegranates was devised by W. E. Sutton.

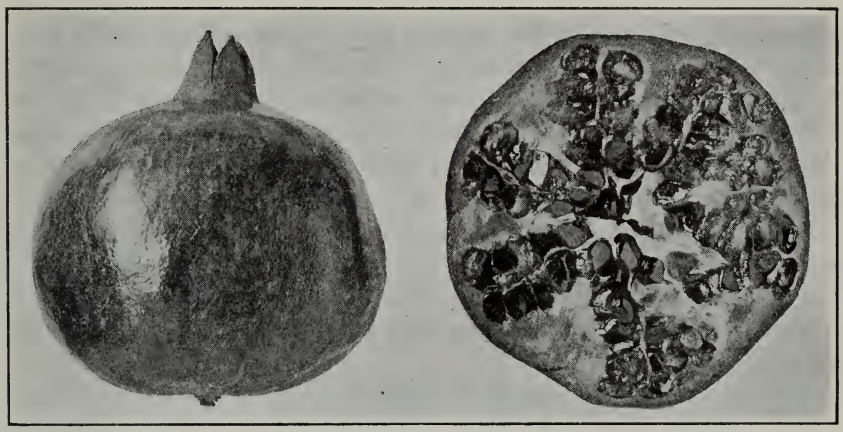

Fig. 8.—The structure of the Wonderful variety of pomegranate showing the location of the arils. (From Bul. 276.)

Prunes.—"Prune juice" is prepared by leaching dried prunes with water. Two general processes are used: one, a warm-water leach, and the second a boiling-water leach. The kind of juice obtained differs with the process used, the first yielding a thin-bodied, clear juice of rather watery consistency, and the second a juice of a heavier body, cloudy, and rather gummy in consistency.

In the warm-water process the prunes are soaked in water at 160°F for several hours, the resulting extract is drawn off and the operation repeated. To make leaching more efficient the diffusion battery principle is utilized. A series of tanks of suitable size, usually 3 or 4 in number, are arranged in line and filled with prunes. Warm water is added to the first tank and after several hours of leaching, the extract from this tank is drawn off, reheated, and added to the second tank. Fresh water is then added to the first tank. After several hours the process is repeated; the extract from the second tank is added to the third, that from the first is added to the second, and fresh water added to the first. The

process is repeated until the first tank has had 3 or 4 leachings after which the prunes in this tank are removed and discarded. After this the tank is filled with fresh prunes and then becomes the last tank in the process. The extract from the last tank in the process is placed in storage and is ready for concentration or bottling. In leaching by this method care should be taken to avoid crushing the prunes, for this results in too cloudy a juice.

In the second process, the prunes are placed in tanks fitted with steam coils, water is added and brought to boiling. After 4 hours the extract is drained off and placed in storage tanks. An additional amount, approximately two-thirds that used in the first leaching, is added next. This water is brought to boiling and allowed to remain in contact with the prunes for 2 hours. The second extract is then combined with the first. During the process the prunes are not stirred in order to avoid obtaining too pulpy and gummy a juice. The prunes remaining after the second leaching contain about 10 per cent soluble solids. They are either discarded or reduced to a pulp by passage through a tomato pulper which also removes the seeds. Diatomaceous earth filter aid is added to the pulp, which is then pressed in a bag-type filter press to recover the remaining juice. After this, the pressed juice is added to the leachings in the tank.

Concentration of the leachings is carried out by open kettle or vacuum pan or a combination of the two methods according to the flavor desired in the finished product. Open-kettle concentration produces a slight caramelized flavor that is thought to be desirable by some people. On the other hand, the vacuum-pan concentrate is said to be lacking in flavor. Juice made by the diffusion-battery principle does not require concentration. It can be readily prepared at 20° Balling, which is the proper concentration for canning or bottling.

Tomatoes.—The tomato fruit is botanically a fleshy berry. Its flesh consists of an outer wall, radial walls or interlocular septae, the placenta, and the core. The seeds are embedded in a jellylike mass of thin-walled tissue which touches but does not unite with the outer or radial walls and which fills the locular cavity when the fruit is mature. The thin-walled cells of the tomato are easily ruptured and the cell sap, or juice, is easily liberated. The juice owes its color to the presence of certain pigments occurring as crystals, or granules, in the cell sap. Were it not for their presence, tomato juice would be a straw-colored liquid rather than a reddish-colored one.

The juice is extracted by crushing and pressing usually in continuous extractors. Tomatoes contain very active pectic enzymes as well as active

oxidizing enzymes. To avoid the changes in body and vitamin-C content brought about by the unrestricted activity of these agents, tomatoes are scalded before pressing. After leaving the washer and trimmer the whole tomatoes pass through a belt scalder in order to heat them *thoroughly* before they are discharged into the hopper of the juice-extracting machine. The preheating more completely excludes air by the heat vapors while the juice is being extracted, gives a better removal of color from the skins, and results in a larger yield of juice.

Two types of extractors are used. In one the tomatoes are fed into a hopper, containing a slowly revolving cutter or crusher. The tomatoes, after being cut into small pieces, pass into the screen section of the machine and come into contact with two roughened rollers. These rollers revolve in the opposite direction to the way they are turning within the screen. This squeezing action extracts the juice. Two metal paddles within the screen move with the rollers and lift the pieces of tomato so that the rollers will press every piece and move the squeezed portions along the screen to the discharge opening.

In the other type of extractor the juice is extracted by the pressure exerted by a large helical screw revolving in a cylindrical screen so adjusted as to reduce aeration of the juice to a minimum.

STRAINING, FILTRATION, AND CLARIFICATION

Fruit juices, after extraction from the fruit, will contain suspended matter varying in type and quantity with the method used in extracting the juice. The larger pieces of fruit particles, obtained from the tissues surrounding or containing the juice, particularly seeds, skins, and other foreign matter, add neither to the appearance nor to the flavor of the juice and result in a more rapid deterioration. The coarse particles are removed generally by the use of screens. The juice also contains finer particles of pulp and various gums, pectic substances, and proteins in colloidal suspension. The complete removal of all suspended matter, even though it results in an increased stability and an improved appearance, is not always desirable since the brilliantly clear juice often lacks the color, flavor, and nutritive value of the expressed juice. Early in the development of the fruit-juice industry, and before the widespread use of the can, all fruit juices were rendered brilliantly clear and were stabilized against the later precipitations of gums and other colloids or of crystals, such as cream of tartar. The trend today, with few exceptions, is toward a cloudy, or pulpy, fruit juice. The can and the opaque or dark-glass container now coming into favor mask the unattractive

separation of the fruit fibers from the juice. However, a considerable amount of commercial cider and grape juice is still clarified.

The removal of the suspended particles of fruit tissue may be effected in a variety of ways: by settling, by straining, or by filtering. The removal of the finely divided particles in colloidal suspension is more difficult. Filtration, either alone or after some process such as flash pasteurization (p. 31) or treatment with various fining agents, may be used; or the juice may be cleared by settling after such treatment as will result in the ready precipitation of the suspended particles. *Filtration* is a mechanical means of removing the suspended particles by forcing the juice to pass through a filter medium, the pores of which are so small that they do not allow the particles to go through. *Clarification* is a process of precipitating the finely divided particles by the addition of substances which act either directly upon the colloids to cause their precipitation or indirectly by forming, with some constituent of the juice, flocculent precipitates which on settling carry with them other suspended matter.

Straining.—The desired color and flavor of juices such as orange and tomato are due to a large extent to the suspended particles which they contain. The juice sac of the orange contains small particles, chromatophores, which contain the carotinoid pigments that give the juice its orange color and much of its aroma. The filtered juice is straw-yellow in color, lacks fruity aroma, and is rather insipid. It is much more stable, however, and easier to preserve. The orange juice prepared at present is strained to remove as much as possible of the coarse suspended matter and leave only the minimum amount of chromatophores necessary to give its characteristic color, flavor, and aroma. Seeds, carpellary membranes, and tissues other than the chromatophores should be removed as completely as possible. This is accomplished by straining the juice by means of rotating cylinders of perforated metal screen with baffles, stationary cylinders with slowly revolving helical screws or paddles, or conical screen and conical helical screw expellers. Centrifugal strainers are also coming into wider use. The strainers must be built of corrosion-resistant metals, such as aluminum, nickel alloys, or stainless steels, and must be so operated as to produce the minimum of aeration. The strainers are often a unit of the extractors which both extract the juice and strain it.

Filtration.—The juice to be filtered may be forced through the filter media by gravity or hydrostatic head, suction, or pressure. The filter media may be finely woven cloth, either canvas or metal; fiber or asbestos pads (fig. 9); cotton pulp or disks; porous porcelain ware or wood. The

rate of filtration depends upon the area of the filtering surface, the pressure differential, the concentration, size and structure of particles, and the size of the filter pores. The suspended particles are usually soft and amorphous and tend to pack together and clog the filter pores. In order to minimize this sliming and clogging effect, the filter medium is coated with diatomaceous earth, which is also added to the juice as a filter aid. Since even the fired filter aids give the juice an unpleasant

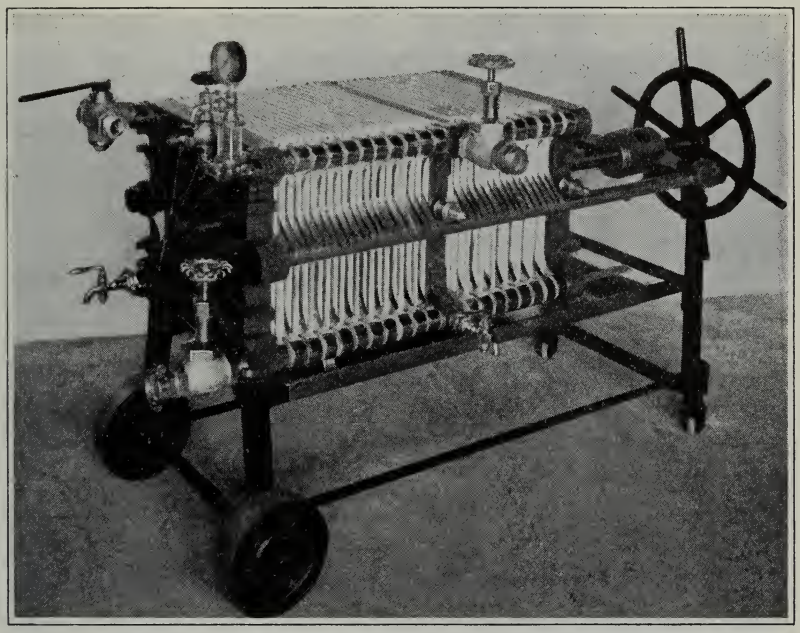

Fig. 9.—An asbestos-pad filter for large-scale filtration.

earthy taste when not completely removed or used to too large an extent, as little as possible of the filter aid should be employed. When properly used the effect on flavor is small and may be further minimized by boiling the filter aid with 1 per cent tartaric or citric acid solution before use.

The simplest filter is the bag filter, which consists of a conical heavy duck, or felt, bag which is used in the same manner as an ordinary jelly bag. The rate and effectiveness of filtration may be increased by the addition of infusorial earth to the juice before filtration. Bag filters commonly hold 10 gallons of juice at each filling. They are satisfactory only for small-scale operations.

For larger-scale manufacture of fruit juices some form of pulp filter, leaf-type filter, or filter press is generally used. Pulp filters vary greatly

in appearance and design. They consist of several thick disks of cotton pulp in a tin-lined copper cylinder. The disks of pulp are separated by metal screens, and the juice is admitted to the cylinder in such a way that each layer of pulp acts as an independent filter which thus gives a very large aggregate filtering surface. After use, the pulp is washed in water by stirring with a mechanical agitator, pressed into disks, and used again in the filter. A filter of this type, using only two disks, has proved satisfactory for small-scale operations.

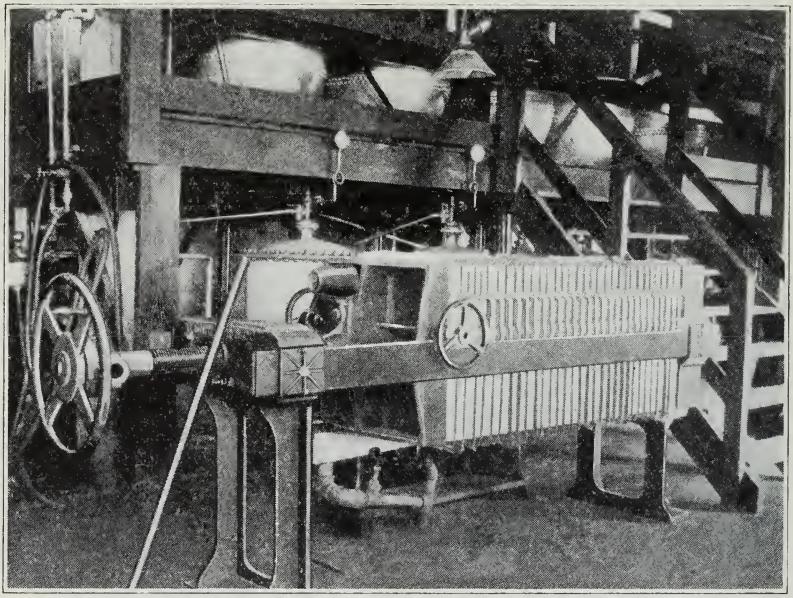

Fig. 10.—A filter press in use in a New York grape-juice plant.

The leaf-type filter consists of several perforated metal screens through which the juice is forced. These metal screens are coated either with diatomaceous earth or with asbestos fiber. This forms the filtering surface. In the filters using asbestos fiber, the first juice to be passed through the filter is mixed with asbestos fiber of a special grade. The fiber gathers on very fine silver-plated metal screens enclosed in a cylinder or cabinet. The use of the special fiber in this filter polishes the juice and gives it a permanent brilliancy. In the leaf-type drum filters using diatomaceous earth, the filter aid is generally used for precoating and filtering.

Filter presses (figs. 10 and 11) are used in many industries for filtering large volumes of various liquids and have also been used successfully

for fruit juices. With these, filtration is accomplished by forcing the liquid under heavy pressure through cloth or canvas sheets, precoated with diatomaceous earth, held between metal or wooden plates. Filter aid is also added to the liquid to be filtered.

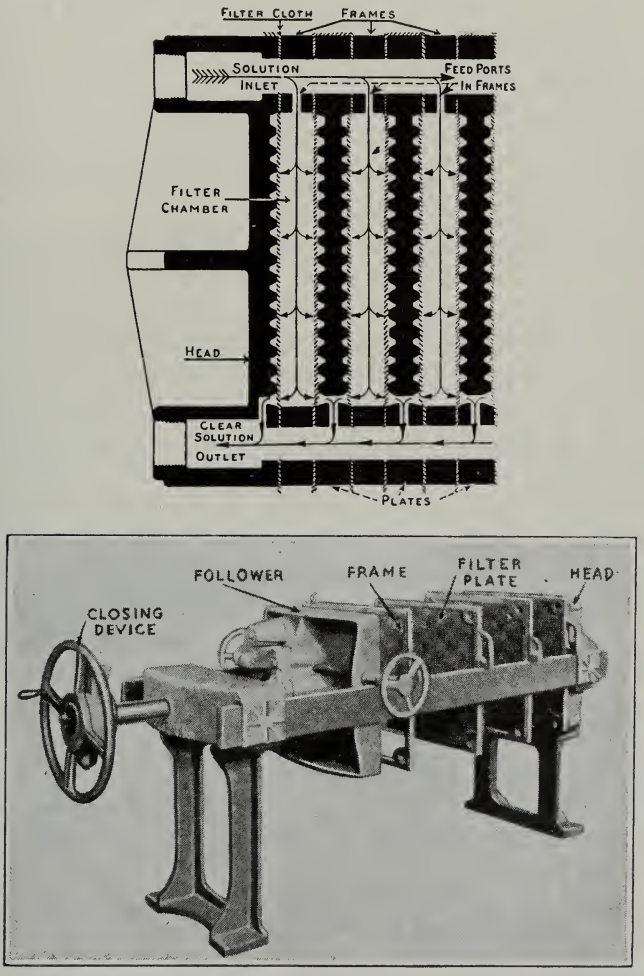

Fig. 11.—Essential features of the filter press and assembly.

The efficiency of the operation of filter presses depends upon the manner in which the precoat charge is laid on the cloths, upon the amount of filter aid added to the liquid to be filtered, and the care taken to hold the filter aid in suspension by constant agitation. For best filtration results, every gallon of liquid being filtered must carry the proper quantity of filter aid, held in uniform suspension throughout.

The filtration of fruit juices is markedly hastened and facilitated by previous heating or other means of clarification.

Clarification by Fining.—The bulk of the suspended matter, particularly in apple juice, consists of protein and pectinlike substances. These colloidal substances carry an electrical charge, generally negative, and are precipitated when this charge is reduced to zero by the addition of a colloid bearing an electric charge opposite in sign to that of the colloid to be removed. Gelatin and casein act in part in this manner and in part by forming insoluble precipitates with the constituents of the juice (casein with acid, gelatin with tannin) which on settling carry with them other suspended particles.

The gelatin-tannin process is the most widely used colloid-precipitation process for clearing fruit juices, but since the chemical reaction involved must be accurately adjusted for each juice and each type of gelatin used, considerable time and experience are necessary in making the required tests. Laboratory tests are first conducted to determine the correct amount of gelatin to add for the juice to be treated. Since there is danger of clouding the juice by the use of too much gelatin, tannin is usually added so that no excess of gelatin remains. The addition of tannin to the juice also helps to minimize the bleaching of the color that occurs during a gelatin-tannin clarification, since the added tannin helps to replace the natural tannins of the juice removed during clarification. In commercial practice about 1.25 ounces of tannin and from 1.5 to 6.0 ounces of gelatin, according to the condition of the juice, are required per 100 gallons. The tannin is added first to the juice, the juice being well stirred; next the gelatin solution, the juice being agitated during and for several minutes after the addition of the gelatin solution. After this the treated juice is allowed to stand undisturbed for 18 to 24 hours for the precipitated matter to clot together and settle out. The clarified juice is then siphoned off the sediment, care being taken not to disturb the latter.

Clarification by Enzymes.—Another widely used process of clarification, particularly for apple juice, is by the use of enzymes. These transform pectin into insoluble pectic acid which on precipitation carries down other suspended matter. Starch-liquefying enzymes are also used. The most widely used enzyme preparation for clearing fruit juices consists of pectin-splitting enzymes prepared from the mold *Penicillium glaucum*. Hydrolytic enzymes, prepared from the mold *Aspergillus oryzae,* are also used. There has been some objection to the enzymatic clarification of fruit juices owing to the formation of some sediment on prolonged storage. However, if enough enzyme is added to change com-

pletely all the soluble pectin into sugar and other substances, including some insoluble material which precipitates out together with turbid colloidal substances that have lost the protective influence of pectin, the after sedimentation is very slight or absent. Too much of the enzyme should not be used since it may be responsible for some after-precipitation. The amount to use depends on the type and activity of the enzyme, the amount of suspended matter in the juice, the composition, particularly the acidity of the juice, and the temperature and time of storage. The storage period should be short enough to prevent fermentation or other undesirable changes. The lower the temperature the longer the storage period necessary to cause the desired chemical decompositions of the colloidal material by the action of enzymes. After clarification by enzymes the juice must be heated to 150°F to stop any further action of the enzymes.

Clarification by Heating.—The most universally applicable and in many respects the most positive process of clarifying depends on the fact that the colloidal material in fruit juices is usually coagulated by heating and will settle out readily or can be removed by filtration. To effect the coagulation of the colloids without materially changing the flavor of the juice it is best to heat the juice rapidly to temperatures of about 180°F, hold at that temperature for 1 minute or less, and then cool promptly. The heating should be done in the absence of air to avoid the undesirable effects of oxidation and to minimize loss of volatile aromatic constituents.

Heating in a closed system, such as is furnished by a tubular heat interchanger or flash pasteurizer, is desirable (fig. 12). Flash pasteurization is generally accomplished by passing the juice, usually by centrifugal pump, through metal tubes encased in larger external tubes through which steam or hot water is circulated. The tubes through which the juice is pumped may be flattened to increase the rate of heat transfer or they may be bent in the form of a flat ribbon spiral. The juice, in such a system, may be brought rapidly to temperature, held for the required time, and promptly cooled in a continuous manner. The tubular heater should be operated so that the juice is heated, preferably by hot water, in part of the tubes forming the assembly and cooled in others so that it leaves the heater cold. If necessary, steam-jacketed jelly kettles may be used, but their use even under the best conditions causes some scorching, and appreciable oxidation and loss of aroma and flavoring materials. The heat-treated juice is next mixed with filter aid and filtered.

An important advantage of clarification by heating is that it removes those substances which would otherwise precipitate by heat during the

preservation of the juice by pasteurization. A good principle to follow with juice to be preserved by pasteurization is always to heat before canning or bottling to a temperature at least as high as that used later.

Clarification by Freezing.—The freezing of cloudy fruit juices often facilitates their clarification because freezing so alters the character of the colloidal material present that it readily precipitates when the juice is thawed. This denaturation of colloids is a well-known phenomenon

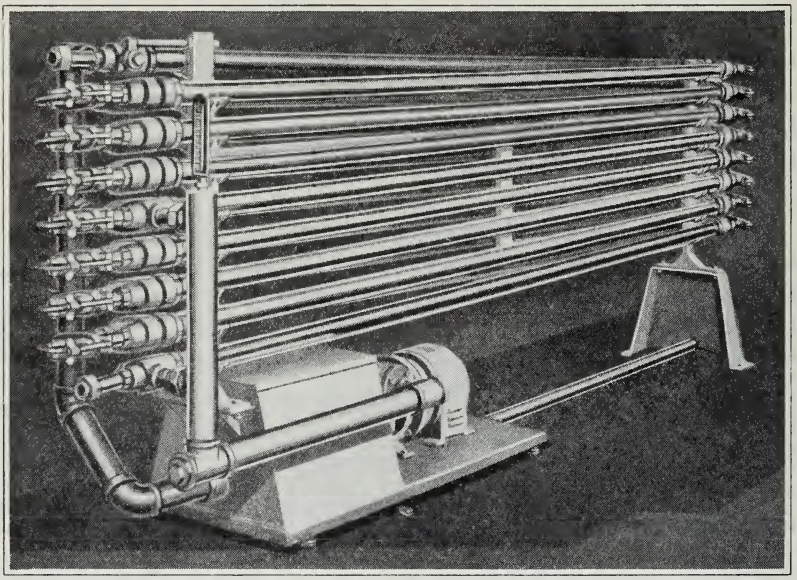

Fig. 12.—A tubular heat interchanger with sanitary fittings suitable for flash pasteurization of fruit juices.

and is apparently due to the combined effects of concentration and dehydration. This effect is particularly noticeable in apple juice, although it has also been observed with grape, berry, and citrus juices.

Detartrating Grape Juice.—Freshly extracted grape juice differs from other juices in containing not only suspended fragments of tissue and various colloids but also cream of tartar in supersaturated solution. This cream of tartar slowly precipitates in the form of slightly acid, fine, gritty crystals. Since the presence of these crystals in the juice is objectionable it is necessary to remove them before bottling. The riper the grapes the higher the cream-of-tartar content. Practically all the tartaric acid in California grapes and much of that in eastern grapes is present as cream of tartar.

The usual commercial procedure of removing the excess cream of tartar is to heat the juice, after straining, to about 180° F in steam-

jacketed aluminum kettles, fill hot into previously steamed, clean 5-gallon carboys, seal with paraffined cork, then cool by passing through a cooling tunnel, and store under refrigeration for several months to complete the precipitation. After storage for the required length of time the cleared juice is siphoned off the lees. Separation of cream of tartar is hastened by low temperatures. Hartmann and Tolman[7] found that precipitation of cream of tartar at the end of a storage period of 4 months was 31 per cent and at the end of 16 months about 48 per cent of that present. Lathrop and Walde[8] showed that storage for 6 days at 20° to 25° F resulted in the precipitation of more than 50 per cent of the cream of tartar.

The more rapid precipitation of cream of tartar by freezing storage, as a result of both low temperature and concentration by separation of water as ice crystals, is now well known. Freezing not only results in a more rapid and more complete separation of cream of tartar but also improves the clarity of the juice by depositing much of the colloidal material. Two low-temperature processes are now in use. In one the juice, after pressing, is cooled to about 30° F in a continuous tubular cooler, either with cold water followed by refrigerated brine or by brine alone, and then stored in large tanks in cold-storage rooms in which the juice is maintained at about 28° F. At this temperature the grape juice usually freezes into slush ice at the surface. Such juice is stored until the argols (principally cream of tartar) are precipitated, and then filtered.

In the second low-temperature process, or freezing process, the juice in 50-gallon barrels or in special 10-gallon enameled tin cans is frozen in freezing rooms held at about 0° F. The frozen juice is thawed out and decanted or siphoned off the sediment. Usually so much of the cream of tartar is thrown out that the juice may become too low in acidity. If necessary some citric acid may be added. To facilitate the more rapid handling of the frozen juice, freeze it in slipover-top enameled tin cans, remove these from the freezing room, warm the outside of the cans with hot water, slip out the frozen cake of juice into the hopper of an ice crusher, crush or shave the juice into large vats equipped with heating coils, and defrost by heating with warm water. Contrary to popular opinion, the rate of re-solution of the cream-of-tartar crystals is so slow that the juice may be completely defrosted and brought to room temperature before filtration without materially increasing in cream-of-tartar content.

[7] Hartmann, B. G., and L. M. Tolman. Concord grape juice: manufacture and chemical composition. U. S. Dept. Agr. Bul. 656:1–26. 1918.

[8] Lathrop, C. P., and W. Lowe Walde. Change in Concord grape juice composition by freezing storage. Fruit Prod. Jour. 7(5):26–27. 1928.

DEAERATION

Fruit juices in general, and citrus juices in particular, deteriorate in color and flavor on exposure to air, especially during heating and storage. Even the more stable juices, such as apple and grape, lose much of their fresh aroma, become cloudy, and discolor in the presence of air. For this reason it is desirable to minimize the exposure of the juice to air during extraction, straining, and other treatment.

Because of the presence of air in the intercellular spaces of the fruit and because of the difficulty of extracting the juice without some aeration, the extracted juice usually contains appreciable quantities of oxygen. Much of this oxygen is present on the surface of the fruit particles; some of it is dissolved by the juice, and at first only a small portion is fixed by the constituents of the juice as peroxides. Therefore if the juice, soon after extraction, is subjected to a high vacuum, a great deal of the oxygen, as well as other gases, may be removed before it has become fixed by the juice. The deaeration is best accomplished by drawing the strained juice into an evacuated vat, or tank, so constructed that the juice is sprayed into it in a fine mist or as a thin film. After partly filling the vat the juice is held under a vacuum of at least 27 inches for about 10 minutes. The vacuum may then be relieved, preferably with an inert gas such as nitrogen, or with air. Since much of the gas is present on the fruit particles and these become soaked with juice on losing their gas during vacuumization, the reabsorption of air by deaerated juice is small. Usually the deaerating unit is connected with the pasteurizing unit so that the juice does not come in contact with air until it issues hot from the pasteurizer into the filter. The blanket of steam over the juice further protects it from oxidation.

METALLIC CONTAMINATION

During all stages of handling, from the extraction to the final packaging, the juice should be protected from contamination with metals. Contamination with metals, such as zinc from galvanized ware or lead or cadmium from plating, solder, or alloys, must be strictly avoided since the salts of these metals are extremely toxic. *The sale of juice containing toxic substances is prohibited by law.* Contamination with iron and copper is undesirable because of the adverse effect of these metals upon the flavor of the juice. Not only do they impart an objectionable metallic flavor but they also hasten certain undesirable changes. In California Valencia-orange juice, the concentration of metal detectable to taste was found to be 20 p.p.m. for copper, 30 to 40 p.p.m. for ferrous iron, and

about 100 p.p.m. or over for ferric iron, aluminum, chromium, nickel, and tin. Shrader and Johnson[9] found that copper and iron imparted off-flavor to Florida orange juice when present to the extent of 5 p.p.m., chromium at 30 p.p.m., tin over a range of 15 to 60 p.p.m., while aluminum and nickel did not impart any flavor.

La Que[10] found that when aluminum, chromium, copper, iron, nickel, tin, and zinc were added to tomato juice in quantities up to 80 p.p.m., only copper had a definite effect on flavor. This could be detected at concentrations above 16 p.p.m. Furthermore, no effect on color was observed other than by copper, and this was detectable at 16 p.p.m. and not at 6 p.p.m. Similar results have been reported for other juices.

In order to avoid the effect of metals upon color and flavor it is necessary to use equipment made of glass, or steel lined with glass or suitable enamel, or to use corrosion-resistant metals. Aluminum, nickel, certain nickel-copper alloys, and certain stainless steels have been found suitable.[11] Much of the metal used for equipment in modern juice factories is stainless steel.

PRESERVATION PROCESSES

Fresh fruit juices may spoil in many ways. They may spoil through fermentation, molding, or souring caused by the growth of yeasts, molds, and acid-tolerant bacteria capable of growing in the fruit juice. They may spoil through the activity of enzymes secreted by the fruit tissues which may bring about changes in color and flavor or cause formation of unsightly precipitates. Or they may spoil by the chemical reaction between certain of the constituents of the juice or between the juice constituents and oxygen of the air or the metal walls of the container.

The yeasts and most of the acid-tolerant bacteria are readily destroyed by heating the juice to about 150° F for several minutes; some bacteria, particularly certain spore-forming bacteria that may be found in tomato juice, are more heat-resistant and require heating to 190° F for several minutes. The mold spores are more heat-resistant than the yeasts and are destroyed at higher temperatures at about 175° F for 5 or 10 minutes. However, they need air for their growth, and juice sealed in completely filled containers, under vacuum or after charging with carbon dioxide need not be heated to temperatures high enough to destroy

[9] Shrader, J. H., and A. H. Johnson. Freezing orange juice. Indus. and Engin. Chem. 26:869–74. 1934.

[10] La Que, F. Corrosion resistance of materials for pea, corn and tomato processing. Internatl. Nickel Co. Bul. TS-8:1–12. 1935.

[11] For further information see the articles on corrosion in the "Selected List of References."

mold spores. Some of the enzymes are readily destroyed by heating to moderate temperatures, or, like the mold, need air for their activity. The pectic enzymes, however, which cause the undesirable clearing of citrus juices and the clotting of the fruit particles they contain, or the jellying of unfiltered apple juice, are more heat-resistant, requiring at least 4 minutes at 185° F, 1 minute at 190° F, or a fraction of a minute at 195° F. Since enzymes of this type are also involved in some of the changes in flavor that occur in citrus juices and some of the other juices, their destruction results not only in a better-appearing juice but also in a better preservation of flavor.

In addition to heat, other agencies have been suggested for the destruction of the microörganisms capable of spoiling the juice, for example, the use of electric energy in the form of ultraviolet rays, X rays, ultrasonic waves, or by direct electrolysis; or by the use of the strongly bactericidal powers of silver in very small concentrations. None of these methods have proved to be dependable under the existing commercial conditions.

The activity of microörganisms may also be prevented by making the conditions unfavorable to their growth, as by low-temperature storage of the juice or by the addition of the permitted chemical preservatives, benzoic acid and benzoates or sulfurous acid and its salts. Close filtration of the juice may be used to sterilize the juice and is satisfactory only provided the juice is not reinfected during bottling or canning.

Pasteurization.—Heating the juice to a temperature and for a time sufficient to destroy those microörganisms capable of growing in the juice is the most important method of preserving the juice. Pasteurization, however, must be carried out under conditions that will not impair the flavor of the fruit juice. Too high a pasteurizing temperature or too long a period of heating impairs the fresh-fruit flavor and imparts a cooked taste. To overcome this objection two processes of pasteurization have been developed: low-temperature heating for relatively long periods, or heating for a very short period, about 1 minute, at high temperatures.

The higher the temperature of heating, of course, the shorter the time of heating necessary to destroy the microörganisms or enzymes. Thus, for wine yeast in apple juice, Cruess, Aref, and Irish[12] found the following periods of heating at the various temperatures:

Minutes	° F	Minutes	° F	Minutes	° F
2	145.0	20	132.6	60	129.5
10	134.6	40	130.6	120	127.9

[12] Cruess, W. V., H. Aref, and J. H. Irish. Pasteurization investigations. Fruit Prod. Jour. 12:358–59. 1933.

They found that temperatures of 150° to 160° F were sufficient to preserve fruit juices if (*a*) oxygen is displaced by carbon dioxide, or (*b*) if the oxygen is removed by vacuumization and the juice sealed under high vacuum, or (*c*) if the oxygen is removed by vacuumizing or washing with nitrogen and displaced by nitrogen, or (*d*) if the juice is packed in tin containers without the precaution of removing oxygen by vacuumizing or by displacing it with an inert gas such as carbon dioxide, nitrogen, helium, etc. They were successful in preserving bottled carbonated apple juice by pasteurizing at 140° F for 30 minutes or at 130° F for 2 hours even though it was heavily contaminated with yeast and mold spores. The uncarbonated bottled juice pasteurized under the same conditions became moldy. When the juice was canned and heated in cans for 30 minutes at 140° F no spoilage occurred even in uncarbonated juice. The juice pasteurized at 140° F or less was of fresh flavor. However, although this temperature was high enough to destroy yeasts, it was not high enough to destroy pectic enzymes. One lot of juice from ripe apples was observed to become jellified in cans in storage for several weeks. Although low-temperature pasteurization may be used for apple juice low in pectin content, either naturally or made so by enzyme treatment, and for certain other acid fruit juices, it is not suitable for citrus juices because of the high heat resistance of its pectic enzymes, and it is unsafe for tomato juice because of the danger of spoiling by heat-resistant bacteria.

In the flash-pasteurization process the juice is heated rapidly to temperatures of 190° F, held there for about a minute, cooled to a suitable filling temperature, filled into suitable containers which are then closed, inverted to sterilize the seal, and promptly cooled. To avoid overheating, the juice must be brought rapidly to temperature and then promptly cooled so that it is exposed to high temperatures for but a short interval. This process in conjunction with deaeration is finding favor not only in the citrus-fruit-juice industry for which it was chiefly developed, but also for use with other fruit juices. The filling temperature depends on the container to be used, whether tin or glass, type of seal, and type of juice. Orange juice is generally filled into cans at 175° F.

Heat Transfer Determinants.—In the pasteurization of fruit juices after bottling or canning, sufficient heat must be transmitted through the wall of the container to raise the temperature of the entire contents to the pasteurizing point. When the container is placed in the pasteurizer, heat enters from all sides, and the surface of the contents rapidly reaches the pasteurizing temperature. The rate of heat transfer from the bath to the container depends on the temperature gradient between

them, on the nature of the heating medium (it being faster for water than for steam), and on the velocity of flow of the heating medium over the surface of the container. Heat transfer through the walls of the container to the surface of the liquid in it depends chiefly on the conductivity and thickness of the walls and is relatively fast. The air in the headspace usually allowed in bottles acts as an insulator and it is good practice to lay the bottles on their sides in order to assure the sterilization of the inside of the cap. Cans are exhausted before closing and are filled more completely so that there is less danger of incomplete sterilization of the inside surface.

The rate of heat penetration from the surface of the container through the mass of liquid is determined largely by the nature of convection currents. If the viscosity of the fluid is such as to impede convection currents the rate of heat penetration into the interior is slow. Where the viscosity is low enough to freely permit convection currents, the temperature in the center will rapidly reach the pasteurizing point, although the time required will depend also upon the size and shape of the containers.

The most practical method of increasing the rate of heat transfer is by agitation of the container. This not only insures a more uniform heating of the juice, but also reduces the period of heating and thus lessens the production of "cooked" flavor in the juice. Continuous agitating pasteurizers, particularly for cans, are now available which so increase the rate of heat penetration into the container as to markedly reduce the necessary time of heating. These pasteurizers are constructed either so that the can rolls or so that the can is actually agitated in a jarring manner.

Freezing.—Freezing is an ideal way of preserving fruit juices, particularly those very susceptible to injury in flavor by heating, since the frozen juice retains practically all its fresh flavor and color when suitably prepared and frozen. However, because the juice has to be defrosted before use as such and because of the marketing difficulties encountered, freezing is used largely for the purpose of extending the operating season of canneries and preserving plants. In order to retain its fresh flavor the juice should be chilled and frozen as soon after extraction as possible. Citrus juices and certain other juices should be deaerated before freezing to retain their flavor better. The juice may be chilled almost to its freezing point by passage through brine-cooled coils, packed cold into hermetically sealed containers, and frozen as rapidly as possible either in air or brine at 0° F or below. In the frozen form it may be stored indefinitely at 0° to 10° F. The juice may be deaerated, frozen to the consistency of an orange ice in specially constructed verti-

cal ice-cream freezers, and then packaged and frozen. If the juice is deaerated, the vacuum should be relieved with pure nitrogen gas before freezing. The juice may be frozen in small-sized tin cans or paper containers for institution use, or in larger-sized enamel cans fitted with slipover or friction tops. Allowance should be made for expansion on freezing, about 10 per cent headspace in the container being necessary. The dehydrating and concentrating effect that occurs from the mechanical effect of the separation of water as ice, together with the low temperature, results in the destruction of a large percentage of the microörganisms present. Not all the microörganisms are destroyed however. The frozen juice is, therefore, perishable and will spoil by molding or fermentation if allowed to defrost and reach room temperature. For this reason it must be kept under refrigeration until ready for use.

Chemical Preservatives.—Sodium benzoate and sulfurous acid or its salts are the only preservatives permitted by law. The indiscriminate use of chemical preservatives in the past to mask impairment in quality has resulted in a marked prejudice against them. However, they are still widely used in the beverage industry. Sodium benzoate of high quality, when used in concentrations of 0.05 to 0.1 per cent, does not impart a highly objectionable flavor to fruit juices or to a fruit-juice-beverage base, particularly if they are to be diluted before use. Sulfurous acid, whether added as such or as potassium metabisulfite does have an objectionable flavor in concentrations of 0.1 per cent or above. However, it strongly retards oxidation and the resulting discoloration and loss of flavor, and when used in small amounts in conjunction with sodium benzoate is very desirable. The amount of preservative necessary depends on the extent and type of infection and the character of the juice, particularly its acidity. Thus, Cruess, Richert, and Irish[13] found that in acid juices, such as citrus juices, 0.1 per cent of sodium benzoate was sufficient, but in less acid juices, such as those from very ripe apples or grapes, at least 0.3 per cent was necessary. The concentration of metabisulfite or sulfite as SO_2 necessary to prevent growth in an acid juice is about 0.1 per cent. When used to inhibit oxidation about 0.02 per cent of SO_2 is sufficient for ordinary conditions where the juice is stored in sealed containers. The preservative should be completely dissolved and thoroughly mixed with all the juice to be treated.

Sodium benzoate varies greatly in quality. Some grades possess a medicinal "iodoform" taste and odor that renders them wholly unfit for use in fruit products.

[13] Cruess, W. V., P. H. Richert, and J. H. Irish. The effect of hydrogen-ion concentration on the toxicity of several preservatives to microörganisms. Hilgardia 6(10): 295–314. 1931.

One-tenth of 1 per cent corresponds to about 7 ounces of sodium benzoate to 50 gallons of fruit juice, or to about 8 ounces to 50 gallons of 50° Balling sirup. The benzoate should be weighed and then dissolved in water before adding to the fruit juice. A solution containing 1 pound of sodium benzoate dissolved in water and diluted with water to 1 gallon makes a solution of convenient strength. One pint of this solution contains 2 ounces of sodium benzoate. After addition to the juice or sirup the liquid must be thoroughly stirred to insure mixing.

Carbonated bottled fruit beverages keep satisfactorily with 0.05 per cent of sodium benzoate, that is, $\frac{5}{100}$ of 1 per cent. The amount of benzoate necessary to give this concentration in the bottled beverage is added to the sirup. Thus, if 2 ounces of sirup is used to a 6-ounce bottle, then the sirup must contain 0.15, or $\frac{15}{100}$ of 1 per cent of sodium benzoate. *The presence of sodium benzoate or other chemical preservatives must be declared in prominent type on the label.*

Sterilization by Filtration.—Several germ-proof filters are now available for the sterilization of fruit juices. These filter out the microörganisms which the juices contain. By properly operating asbestos pad filters, porous candle filters, or other suitable sterilizing filters, it is possible to remove all microörganisms. Juice that is to be sterilized by filtration should be previously clarified and roughly filtered, otherwise the filter pores become quickly clogged with suspended colloidal material.

Not all fruit juices may be sterilized by this means, since many of them depend on suspended matter for color and flavor. In others close filtration usually results in loss in body and a thin-tasting juice. Furthermore, there is danger of contamination during filling into containers or from the containers or the seals. Sterilization filtration has been tested experimentally in this country for apple and grape juices and is used commercially to a limited extent. In one process, grape juice after filtration through a germ-proof filter is stored in sterile tanks under an atmosphere of carbon dioxide gas until ready for bottling. Several installations of this type have been made, particularly in South Africa. This process is worthy of further testing.

Preservation by Other Methods.—The possibility of sterilizing fruit juices by electrical energy has attracted much attention and many patented processes for this purpose have rapidly come upon the market.[14] Usually these processes utilize electrical energy in the form of alternating or direct current, X rays, ultraviolet light, ultrasonic waves, or two or more of these combined. The use of electrical current for sterilization

[14] Tracy, R. L. Sterilization of fruit juices by electricity. Fruit Prod. Jour. 10: 269–71. 1931.

is not new. Wine was treated as early as 1868, and processes for treating milk were described in 1909. The most favorable results in milk sterilization have been obtained by alternating current. However, the action of alternating current is not due to some mysterious power of electrical energy, but to the heat produced by the resistance of the cells and the medium to the passage of electrical current. The apparent advantage of alternating current lies in the absence of localized overheating. Direct current cannot be used because of the marked changes in flavor and color of the fruit juice as a result of electrolytic changes.

Light of very short wave length has been known to possess strongly bactericidal as well as chemical activity. However, complete sterilization is difficult to obtain by its use unless the juice is exposed in layers thin enough to allow complete penetration. The ultraviolet rays and X rays are readily absorbed by the juice when irradiated in too thick a layer, and therefore do not destroy organisms protected by thick layers or opaque particles. Furthermore, such irradiation produces ozone and ozonides even in the absence of air and gives to the juice an unpleasant "burnt-feather" odor. It also results in loss of vitamin C.

Sound waves of high frequency, ultrasonic waves, also have the ability to destroy microörganisms and certain enzymes, but destruction by their use is rarely complete and relatively inefficient.

Of the many other proprietary processes for sterilizing fruit juices, the most promising is a process which makes use of the oligodynamic properties of silver. In this process the juice is either filtered through a silver-bearing sand or is electrolyzed by silver electrodes at a very low current strength. In this way the juice picks up a sufficient concentration of silver ions, about 2 p.p.m., to render it sterile and immune to the attack of microörganisms. Although this process has been used commercially, particularly in Germany, for the sterilization of vinegar and drinking water it is not in commercial use in the fruit-juice industry of the United States. Furthermore, the contamination of the juice with silver may constitute a public health hazard.[15]

[15] Gibbard, James. Public health aspects of the treatment of water and beverages with silver. Amer. Jour. Pub. Health 27:112–19. 1937.

BOTTLING OR CANNING

At one time glass bottles were the usual final containers for juices. Cans were not found suitable at first because of the undesirable effect of tin on the color and flavor of the juice and because of heavy losses from hydrogen swells and pinholing. However, as more resistant tin plates have been developed and special linings devised to protect the juice against the bleaching action of tin, more of the juices have been packed in cans. Much of the juice today is packed and sold in specially enameled type L plate cans.

Cans have certain advantages: They offer better protection against discoloration by oxidation since the tin plate rapidly fixes all oxygen. Also they give better protection against deterioration by light. They are unbreakable and are lighter than glass containers. Being opaque the cans are satisfactory containers for cloudy juices. Great improvements, however, have been made in bottles. They are now available at lower costs in various degrees of opacity and are made of sturdier glass more resistant to thermal shocks and with better closures designed particularly for juices.

Cans are especially suitable for the packaging of the deaerated, flash-pasteurized juice. The juice is filled hot into the cans at about 175° F. They are sealed automatically, inverted to sterilize the lids, and then promptly cooled by rotating through a mechanically chilled water bath. Citrus enamel-lined cans are used for citrus juices and special berry enamel-lined cans for loganberry and red grape juice, or other colored juices. However, all the bleaching action of the tin plate is not prevented even in these cans, and colored juices should not be stored too long or at too high temperatures in the cans.

The light-colored juices may be packed in unlacquered cans under some conditions. The fresh-fruit flavor of the juice is often better preserved in an unlined tin can but there is danger that the juice will acquire a tinny flavor. A partially lined tin can may be best, one that combines the flavor-protective effect of tin without imparting its undesirable tinny flavor. Packing orange juice in citrus enamel-lined cans having plain tin lids may be desirable.

Bottles can be filled with hot juice, sealed, and cooled; but cooling cannot be accomplished as rapidly as in the can because of danger of breaking the bottle. The bottles should be previously steamed or otherwise tempered with hot water; then filled with the deaerated flash-pasteurized juice at 175° F; capped either with crown caps or with vapor vacuum seals; placed on their sides to sterilize the caps and then allowed

to cool to room temperature. However, resistant glass bottles are available which may be cooled directly in cold water after filling with hot juice. If crown-capped bottles are used these should be filled full to minimize oxidation. The vapor vacuum seals (fig. 13) are applied under a vacuum created by a steam jet so that bottles to be capped with them should not be filled full of juice.

Much of the juice that is now bottled is preserved by "in-the-bottle" pasteurization. In this process the bottles are filled with juice at room

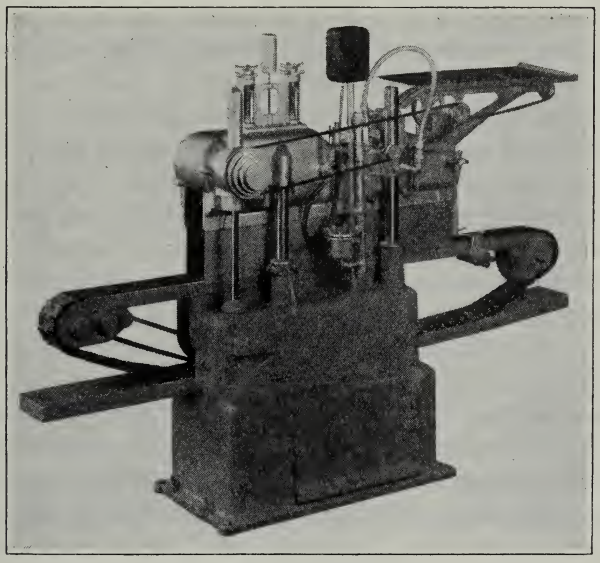

Fig. 13.—Vapor-vacuum-seal closing machine.

temperature, allowance being made for expansion on heating. Quart bottles must be filled to within only about 1½ inches of the top, this space being necessary for expansion of the juice during pasteurizing. An automatic bottle-filling machine will hasten this work. The bottles must be thoroughly washed before use and should, if facilities permit, be sterilized in live steam a short time before filling, but must be cool at time of filling to avoid breaking.

If plain cork-lined crown caps are used they should be placed in live steam or boiling water for a period of about 1 minute just before use in order to destroy mold spores on and in the cork of the bottle cap. Nearly all spoiling of juice in bottles by mold growth is caused by the resistant-mold spores to be found on all such nonsterilized caps. The cork is a poor conductor of heat and thus protects the spores during sterilization of

the juice; hence the need of sterilizing the corks or caps before use. Paper- or metal-foil-lined caps are preferable.

The bottled juice must be heated to a temperature and for a time sufficient to attain a sterilizing temperature at the coolest point, usually the center of the bottle. Agitation during heating will facilitate heat transfer. The bottles are placed in a horizontal position on the false bottom of the sterilizer in order that the juice shall be in contact with the cap and thus make certain that the inner cork disk of the cap reaches the pasteurizing temperature of the juice. If the bottle is in an upright position the air space in the top of the bottle acts as an insulator and prevents the cap from being thoroughly heated. The bottles are covered with water, and the water heated by steam or direct heat to between 176° and 178° F and kept at this temperature 30 minutes for bottles of 1-quart size or less and for gallon size 45 minutes or more. There will be about 2° F difference between the temperatures of the bottled juice and the surrounding water at equilibrium. Cooling after pasteurization may be hastened by slowly running cold water into the bath.

The water is then drawn from the pasteurizer and the bottles placed in a room free from violent drafts of cool air; or they may, if desired, be allowed to cool in the pasteurizer. The latter practice avoids the necessity of handling the hot bottles.

In canning the juice by the in-the-can process, the cans are filled with cold juice, closed under vacuum in an automatic-vacuum-closing machine, and processed in an agitating water bath for the required period of time, which depends on the kind of juice and size of container. Orange and grapefruit juices in No. 1 cans are heated for 10 minutes at 165° F, tomato juice for 20 minutes at 212° F, and other juices for about 20 minutes at 175° F. If a vacuum-closing machine is not used, the juice may be preheated to 165° F, filled hot into cans, sealed, and then processed; or the juice may be filled into cans which are then heated in hot water to 160° to 170° F, sealed hot, and processed. After processing, the juice should be promptly cooled.

To avoid bacterial spoilage in tomato juice Cameron[16] stresses the necessity of keeping contamination at a low level by the application of rigid plant sanitation. He suggests that the juice be heated to 190° F, and filled hot into cans, which should be processed in boiling water at 212° F as follows:

Size of can	Time at 212°	Size of can	Time at 212°
No. 1	15 minutes	No. 2	25 minutes
303	20 minutes	No. 10	40 minutes

[16] Cameron, E. J. Spoilage problems in canning tomato juice and pumpkin. Canner 80(11):7–8, 22. 1935.

The canned and bottled fruit juices, even though they will not spoil by molding, souring, or fermentation when properly pasteurized are not unperishable and change in flavor on prolonged storage at room temperature. This is particularly true of citrus juices. For this reason they should not be stored at too high a temperature or for too long a time. Cool warehousing, and preferably cold storage, is desirable if the storage period is to be very long.

CANNED PULPY FRUIT-JUICE BEVERAGES

Pleasing fruit-juice beverages can be made from apricots, peaches, and certain other fruits by pulping the ripe, peeled, and pitted fruit and canning with sirup. In some cases dry sugar rather than sirup is added. These products are diluted with still or charged water before serving. The following process was described by Shallah and Cruess[17] and is now in commercial use.

Apricot Beverage.—The fresh apricots are picked when thoroughly ripe and after acquiring their deep characteristic orange color and flavor. Although the size is not important, the fruit should be clean and sound.

Whole apricots are washed thoroughly in cold water. They are pitted and steamed until cooked through. This heating kills the oxidase and facilitates the pulping. Ordinarily the heating need not exceed 5 minutes. The hot fruit is run through a brush finisher or tomato pulper equipped with screens of about 1-millimeter holes. It is possible to do the pulping and separate the pits and skins by a single operation, although this depends on the efficiency of the machine and on the degree of ripeness of the fruit.

The purée is sweetened with about an equal volume of cane-sugar sirup of about 15° Balling. The resulting diluted, sweetened purée is filled into plain tin cans, exhausted for 6 minutes at 212 degrees F, sealed, and cooked for 15 minutes at 212 degrees F. Large sizes should receive a longer processing period since the heat penetration through the purée is rather slow.

Another product can be prepared by sweetening the pulped fruit with dry sugar, canning, exhausting, and pasteurizing. It is used as a beverage by diluting it with an equal quantity of water. This gives a very pleasing and appetizing beverage, sweet enough to appeal to the taste of the average consumer.

[17] Shallah, A., and W. V. Cruess. Canning of apricot juice. Fruit Prod. Jour. 13: 205. 1934.

Apricot beverages may be served at breakfast or other meals or used between meals. They have all the aroma of apricots and are probably rich in vitamins A, B, and C. Without dilution, the product can be used as flavoring for milk shakes and in the manufacture of ice cream.

Peach Beverage.—The procedure for making peach beverage is essentially like that described for apricot beverage. Either canning clingstone peaches or juicy varieties of freestone peaches may be used. The fruit should be somewhat riper than for canning as halved peaches.

The fruit is pitted; lye-peeled; heated in a pie-fruit cooker in steam until soft; passed through a tomato-juice extractor or tomato pulper; then if necessary through a tomato-products finisher. About an equal volume of about 15° Balling sirup is added. After this the product is canned, exhausted, sealed, processed in an agitating canned-fruit sterilizer for 15 to 20 minutes, and *very* thoroughly cooled.

CANNED ORANGE DAIRY BASE

The recognized value of orange juice in the diet, including its value as a supplement to milk in the feeding of children, has aroused the orange-beverage producer to the possibility of using the milkman as a distributor of orange juice. Several attempts to distribute freshly extracted orange juice and frozen orange juice have failed for several reasons. Perishability, high cost, and lack of sufficiently complete consumer acceptance of pure orange juice were the more important reasons.

It was found that school children preferred sweetened orange juice to pure juice, and this preference brought about the distribution of an orangeade prepared from pure orange juice. For several years orangeade was distributed to the school children of Los Angeles and the near vicinity. Then came the idea of increasing the distribution of this orangeade to a national scope by making use of the dairies who were serving the schools and other institutions as well as the homes. A sweetened orange juice, fortified with lemon juice, orange oil, and certified food color was developed. This product was canned in gallon cans (fig. 14) and sold to licensed dairies who were furnished attractive glass bottles. The canned dairy base was converted into orangeade at the dairy by dilution with water and sweetening with sugar, bottled, and distributed by the milkmen. Care was taken to prepare the product so that each glass contained the equivalent of 1 ounce of pure orange juice.

The dairy bases are now made by adding sugar to strained orange juice to bring it to the required sweetness, about 50° Balling; citric acid or lemon juice to give it the required tartness on dilution; pectin to aid

in retaining the pulp particles in suspension; and cold-pressed orange oil emulsified in water with pectin. The blended sirup, which may contain some orange juice concentrate, is deaerated, flash-pasteurized, and canned in citrus enamel-lined cans. To improve its appearance the pulp particles may be broken up by passing the juice through a colloid mill.

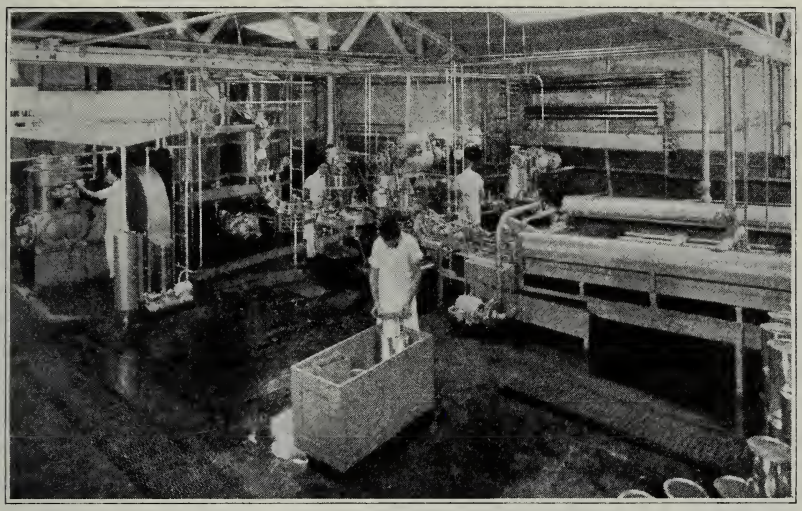

Fig. 14.—Canning dairy orange base. Note the flash pasteurizer at the right.

Formerly, artificial coloring matter was added to dairy bases but this practice is now prohibited by a ruling recently enacted and put into effect by the Food and Drug Administration.

RETENTION OF VITAMIN C IN FRUIT JUICES

Although the vitamin content of juices such as orange and tomato is not their only virtue it has been largely responsible for bringing their use into vogue, particularly for children. Therefore, such juices should be processed so that they retain their original vitamin-C content. Destruction of vitamin C during extraction, clarification, and preservation should be avoided. The vitamin C in tomatoes as well as in oranges is now known to be fairly stable to heat, if oxidation is avoided. Heating in acid solutions, in the absence of air, causes practically no loss in vitamin C, but in the presence of air the loss is marked. The rate and extent of destruction increases with decrease in acidity. Thus, in the more acid fruits such as oranges, the destruction is much less than in the less acid fruits such as tomatoes. Furthermore, fruits may normally contain pro-

tective substances, such as the strongly reducing substances other than vitamin C in oranges, in which respect they differ from lemons, the reducing action of which is due almost entirely to vitamin C itself. Many fruits also contain enzymes which hasten the destruction of vitamin C. These enzymes now are believed to be specific for the oxidative destruction of vitamin C and apparently are not the usual oxidative enzymes such as are involved in the discoloration of apples. Tomatoes are very rich in these destructive enzymes and also are low in acid. Thus, tomato juice suffers more loss in vitamin C than does orange juice if it is not properly treated. Kohman, Eddy, and Zoll[18] found that when cold, processed tomato juice is brought to boiling, about half its vitamin-C content is destroyed, owing to oxidation by air incorporated during the pulping operations.

Extraction under conditions which minimize the amount of air incorporated into the juice and the *prompt* and *thorough* deaeration of the juice will remove sufficient oxygen to markedly reduce this destruction of vitamin C. The destruction by heat of the naturally occurring vitamin-C oxidases is also of benefit particularly if this is done before extraction. Whole tomatoes can be heated with steam and then pressed hot. This results not only in the destruction of the oxidase enzyme but also of the pectic enzymes which would otherwise hydrolyze the natural pectins and give a juice of thin body.

Certain metals,[19] particularly copper, markedly hasten the oxidation of vitamin C by atmospheric oxygen. Copper is active in extremely low concentrations, in the absence of protective substances such as glutathione, proteins, and amino acid. This is another reason for avoiding metallic contamination in processing fruit juices.

CARBONATION OF FRUIT JUICES

Carbonated beverages prepared from cane sugar, citric acid, artificial flavor and color have become popular in the United States not only for the quenching of thirst but also for use in preparing mixed beverages. Many people find that carbonation improves the beverage quality of fruit juices, particularly of those served between meals. However, of the unaltered, pure fruit juices only apple and grape juices are palat-

[18] Kohman, E. F., W. H. Eddy, and Celia Zoll. Vitamins in canned foods. IX. Tomato products. Indus. and Engin. Chem. 22:1015–17. 1930.

[19] Barron, E. S. Guzman, R. H. De Meio, and Friedrich Klemperer. Biological oxidations V. Copper and hemochromogens as catalysts for the oxidation of ascorbic acid. The mechanism of the oxidation. Jour. Biol. Chem. 112:625–40. 1936.

Stolz, Elmer H., Carter J. Harrer, and C. G. King. The chemical nature of "ascorbic acid oxidase." Science 86:35. 1937.

able when carbonated, the other juices require modification such as dilution with water and sweetening with sugar.

Apple and grape juice, particularly when they are high in sugar and low in acid content, are greatly improved by carbonation. Carbon dioxide gas apparently modifies the insipidly sweet taste of such juices. The amount of carbonation is determined to a large extent by the sweetness of the juice. The sweeter and less astringent apple juices are best when carbonated with 2.5 to 3.0 volumes of gas and the astringent, tart juices

TABLE 6

Showing Relation Between Pressure, Volumes of Gas, and Temperature of Water in Carbonating Beverages

Carbonating pressure							
40 pounds		50 pounds		60 pounds		70 pounds	
Degrees Fahrenheit	Volumes of gas (CO_2)	Degrees Fahrenheit	Volumes of gas (CO_2)	Degrees Fahrenheit	Volumes of gas (CO_2)	Degrees Fahrenheit	Volumes of gas (CO_2)
32	6.2	32	7.3	32	8.8	32	9.6
40	5.4	40	6.2	40	7.2	40	8.0
50	4.4	50	5.2	50	6.0	50	6.2
60	3.7	60	3.7	60	4.2	60	4.6
70	2.7	70	3.2	70	3.6	70	4.0

with 2.0 to 2.5 volumes. For well-flavored grape juice a carbonation of 2.5 to 3.0 volumes is sufficient. Excessive carbonation should be avoided since it not only masks the flavor of the juice but also renders pasteurization in the bottle difficult.

In order to obtain the required concentration of carbon dioxide in the juice, two processes of carbonation may be used. One depends upon the fact that the solubility of carbon dioxide increases with decrease in temperature as shown in table 6. The other is dependent upon the fact that the solubility of carbon dioxide increases with pressure.

At low temperatures much lower carbonating pressures need be used to obtain the required carbonation. In this process, which is known as the "low-pressure carbonation system," the juice is cooled to a temperature at or near 32° F, and the carbon dioxide is admitted to the cold juice in a suitably devised apparatus in which the gas is thoroughly mixed with the juice. To charge the juice properly with the gas it is necessary to admit the latter as very finely divided bubbles and mix them thoroughly with juice. A properly charged juice will retain its carbonation during filling and even when the pressure of carbon dioxide is removed. In charging fruit juices it is necessary to use a carbonator

constructed of inert material such as stainless steel or glass-lined metal and to take suitable precautions to avoid excessive foaming which may occur. Not all the available bulk carbonators are suited to the carbonation of fruit juices because of their tendency to permit foaming.

In the high-pressure carbonating system, the gas is admitted into the carbonator at high pressure. At the same time the juice is pumped and sprayed under pressure into the carbonating chamber and is mixed with the gas by a stirring device. This type of carbonator is not so suitable as the low-pressure system for fruit juices, particularly when they are low in tannin.

Carbonated juices are usually packaged in heavy-walled glass bottles. Recently, however, Celmer and Cruess[20] of the Fruit Products Laboratory of the University of California, found that suitably designed cans such as those now being used for the canning of beer are satisfactory containers for carbonated fruit juices. The canned or bottled carbonated juices may be preserved by pasteurization at 150° F for 30 minutes. Owing to the presence of carbon dioxide the growth of mold will not occur in the juices and the pasteurization need be only sufficient to destroy the yeast.

FRUIT-JUICE SIRUPS

Fruit juices sweetened by the addition of sugar and fortified by added flavor and color are in wider demand than the unaltered juices for preparing still drinks or ades and in preparing carbonated beverages. At one time fruit-juice sirups were prepared from several species of fruits, but at present only the citrus products are in much demand. Grapefruit-, lemon-, lime-, and orange-juice sirups are prepared in appreciable amounts for use as bottlers' bases.

These sirups are prepared by the addition of sugar, citric acid, and terpeneless peel oil to the juice. As a rule, the product also contains some juice concentrated under vacuum. At least 7 pounds of sugar is added per gallon of juice, and the product is brought to the required acidity by the addition of citric acid in an amount that depends upon the concentration in the juice and the acidity desired in the finished product. The oil which is added for flavoring is generally added as an emulsion prepared by thoroughly mixing 1 ounce of the oil with $\frac{1}{30}$ ounce of pectin and then stirring in 1 ounce of water. To obtain a stable emulsion the pectin should be thoroughly wetted by the oil before adding the water.

Because of the dilution of the base in preparing the beverage it is customary to add pulp in addition to that present in the juice. Most of

[20] Celmer, Ralph, and W. V. Cruess. Carbonated fruit juices in cans. Fruit Prod. Jour. 16:229, 251. 1937.

the bottlers desire sufficient pulp in the base so that the diluted beverage contains as much pulp as the juice itself. To prevent the separation of the pulp in the beverage, the pectic enzymes must be destroyed by flash pasteurization and a small amount of pectin added.

Most of the beverage bases are artificially colored with a suitable mixture of permitted pure food dyes. However, according to a recent ruling of the Food and Drug Administration artificially colored citrus-juice beverages may not be sold as juices or under the name of the fruit. They can only be sold under proprietary names that have no connection with the fruit.

The fruit-juice sirups may be preserved by flash pasteurization, as in the case of fruit juices, or by the addition of sodium benzoate. The acceptance of sodium benzoate as a preservative by the beverage industry makes its use in sirups not only permissible but often desirable.

In the preparation of carbonated beverages from bottlers' bases the high-pressure carbonating process is employed. Sirup is added at the rate of 1½ fluid ounces per 8-ounce bottle. Carbonated water is then added to fill the bottle to within about 1¼ inches of the top and the bottle is immediately sealed with a crown cap. These carbonated beverages are charged to much higher pressures of carbon dioxide gas than are the juices. At least 60 pounds pressure in the carbonated beverage is used. In preparing the beverages widely used for mixing, a much higher pressure and lower sugar content is used. The carbonated beverages customarily test about 15° Balling and 0.75 per cent total acid.

Fruit sirups are also dispensed at soda-fountain stands. The sirups for this use must be preserved by sodium benzoate and should preferably contain about 50 p.p.m. of sulfur dioxide in order to check browning and discoloration.

Fruit-juice sirups may be prepared from other juices by the addition of sugar, preserved, and used as described for citrus sirups. Most fruit-juice sirups, and citrus-fruit-juice sirups in particular, are subject to decoloration and browning on storage at room temperature. This browning is hastened on exposure to air and may be entirely avoided by storage at 32° F or below. Therefore, it is recommended that such products be stored in cold-storage warehouses and withdrawn as needed.

FRUIT-JUICE CONCENTRATES

Concentrates prepared from fruit juices are used in bottlers' bases, dairy bases, and in preparing other beverages. They are generally prepared by concentrating the juice under high vacuum in specially devised vacuum pans. In the most efficient type of vacuum pan the juice is

heated by passing it through steam or hot-water-jacketed tubes and then spraying it into an evacuated chamber (fig. 15). The process is repeated until the required degree of concentration is attained. To avoid the changes in flavor that occur when the juice in concentrated form is heated, the concentration should not be carried too far. As a rule a 4 to 1 concentration is sufficient, the concentrate being preserved by storage at low temperatures (0°–10° F).

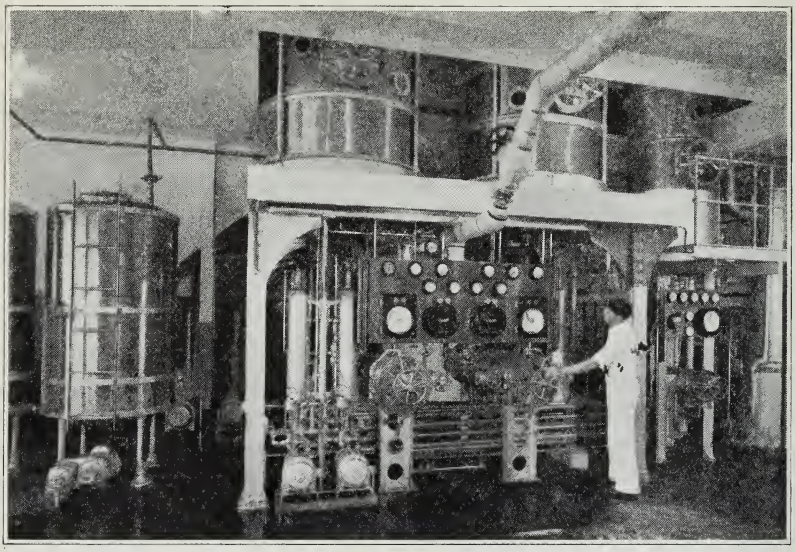

Fig. 15.—Concentrating orange juice in stainless steel pans.

Most fruit juices contain volatile esters and aldehydes that are lost in the usual process of concentration. When these volatile flavoring principles are stable, as in apple and grape juice, the flavor of the resulting concentrate can be improved by the reincorporation of the separated flavor. Several vacuum pans having an ester-impregnation device incorporated in their design are commercially available. The flavoring principles lost in the process of concentrating citrus juices are not stable and should not be returned to the concentrate.

Other devices for the concentration of fruit juices are available and these are discussed in Bulletin 392.[21]

[21] Irish, J. H. Fruit juice concentrates. California Agr. Exp. Sta. Bul. 392:1–20. 1925. Revised 1931.

YIELDS

The yield of juice obtained in commercial practice varies with the condition of the fruit and the method of extraction employed. The approximate average yields which are typical of the various fruits are shown in table 7.

TABLE 7

Approximate Yields of Juice from the Various Fruits

Kind of fruit	Gallons per ton of fruit	Kind of fruit	Gallons per ton of fruit
Apples	140–165	Oranges:	
Berries	160–180	By crushing and pressing	
Grapes, red	160–180	(obsolete process)	130
Grapes, white	140–160	By hand burring	90–100
Passion fruit	65– 95	By an automatic burring	
Pomegranates	90–100	extractor	104–110
Tomatoes	170–190*	Lemons	70– 80
		Grapefruit	110–120
		Limes	70– 80

* Smaller yields are obtained when tomatoes are pressed more lightly.

PLANT SANITATION AND CLEANLINESS

In choosing and arranging equipment in a plant, cleanliness and convenience should be the chief considerations. The floors should be preferably of concrete and so sloped as to provide adequate drainage; too many rather than too few sewers should be provided and these arranged at the bottom of the slope or in troughs. The walls and ceiling should be such that they can easily be kept clean; and all doors and windows should be provided with properly fitting small-mesh screens to keep out insects. The fruit-receiving and storage room should be separate from the extracting and processing room to reduce the amount of infection. The extraction and processing rooms should be so arranged as to make use of gravity flow wherever possible. The equipment should be so arranged as to eliminate unnecessary labor and repeated handling. It should be constructed so that it can be readily cleaned; sanitary pipe fittings should be used throughout; all corners and crevices which might harbor fruit waste and serve as foci of infection should be eliminated. An abundant water supply, and also a sufficient supply of steam should be available for cleaning, and the plant and equipment should be frequently and thoroughly cleaned. Fruit wastes should either be immediately hauled away or otherwise disposed of and not allowed to accumulate.

Thorough washing with hot water and if possible thorough steaming

afterwards is the preferable method of cleaning the equipment. However, if steam is unavailable certain germicidal and detergent preparations may be used to sterilize the equipment and containers. Of these the chlorine compounds, if used with enough alkali, are best. They may be obtained as solutions of hypochlorite in dilute alkali, as powdered hypochlorites—usually calcium salts—or as special preparations such as chloramine-T. The active ingredient in each is chlorine.

Adams[22] states that surfaces which have been washed clean with the usual detergents can generally be sterilized with a hypochlorite solution containing 200 p.p.m. available chlorine. He recommends the following concentrations for the surface conditions specified:

Available chlorine, p.p.m.	
100	For dipping and rinsing (after thorough cleansing) articles that have smooth surfaces (metal, glass, tile, etc.) not subject to heavy contamination.
200	For rinsing and flushing (after thorough cleansing) articles not subject to heavy contamination, but with surfaces difficult to clean.
300	For wiping and spraying (after thorough cleansing) metal, tile, and other smooth surfaces.
600	For wiping or spraying rough surface and general disinfection of premises.
5,000	For combating active outbreaks of mold or bacteria.

The American Bottlers of Carbonated Beverages have maintained for several years a research fellowship at the Iowa State Agricultural College for the development of suitable sanitary measures for the bottling industry. Many of their publications will prove to be of interest to fruit-juice manufacturers.[23]

SUMMARY OF PROCESSES

APPLE

Packed in Glass.—Acid-wash, crush (apple grater), press, deaerate, clarify with enzyme preparation or by freezing and thawing, filter, bottle, pasteurize at 150° to 170° F (see pp. 36–37), cool.

Canned.—Acid-wash, crush, press, deaerate, rough filter (pulp filter) or centrifuge, flash-pasteurize at 190° F, cool to 175° F, can, seal, turn can on side, cool.

[22] Adams, Fred E. Chemical sterilization in the winery. Fruit Prod. Jour. 13:177, 184. 1934.

[23] These may be obtained from Junior Owens, Secretary, American Bottlers of Carbonated Beverages, 726–729 Bond Building, Washington, D. C.

BERRIES

Canned, from Fresh Fruit.—Wash, crush, heat, press, filter, bulk-heat to 175° F, can (in berry enamel-lined cans), seal, invert, cool.

Canned, from Frozen Fruit.—Thaw, crush, press, filter, bulk-heat to 175° F, can, seal, invert, cool.

CITRUS FRUIT

Canned.—Wash, grade (where automatic extracting devices are used), extract juice, strain, deaerate, flash-pasteurize at 190° F, cool to 175° F, can (in citrus enamel-lined cans), seal, turn can on side, cool. Store in cold storage.

POMEGRANATE

Packed in Glass.—Coarsely crush or pick apart, press (in basket type), clarify with gelatin, decant, filter, bulk-heat to 140° F, bottle, seal under vacuum (vapor vacuum seal), pasteurize, cool.

Canned.—Coarsely crush or pick apart, press (in basket type), clarify with gelatin, decant, filter, bulk-heat to 140° F, can (in berry enamel-lined cans), seal under vacuum, pasteurize, cool.

PASSION FRUIT

Frozen Juice.—Burr, strain, deaerate, can, freeze.

Beverage, Packed in Glass.—Burr, strain, deaerate, sweeten, bulk-heat to 120° F, bottle, seal under vacuum (vapor vacuum seal), pasteurize (center should reach a temperature not higher than 160° F), cool.

Beverage, Canned.—Burr, strain, deaerate, sweeten, bulk-heat to 120° F, can, vacuum seal, pasteurize (center of can should reach a temperature not higher than 160° F), cool.

TOMATO

Wash, sort, steam (raise fruit to 165° F), press (nonaerating continuous press), deaerate, bulk-heat to 175° F, can, sterilize, cool.

WHITE GRAPES

Packed in Glass.—Crush, press, bulk-heat to a temperature higher than final pasteurizing temperature, cool, fill into 10-gallon slip-cover enameled tins, freeze (to detartrate), thaw, filter, blend, bottle, seal under vacuum (vapor vacuum seal), pasteurize, cool.

Canned.—Crush, press, bulk-heat to temperature higher than final pasteurizing temperature, cool, fill into 10-gallon slip-cover enameled tins, freeze (to detartrate), thaw, filter, blend, bulk-heat to 150° F, can, seal, pasteurize, cool.

RED GRAPES

Packed in Glass.—Crush and stem, bulk-heat to 160° F, press, bulk-heat juice to temperature higher than final pasteurizing temperature, fill into 10-gallon slip-cover enameled tins, freeze (to detartrate), thaw, blend, bottle, seal under vacuum (vapor vacuum seal) pasteurize, cool.

Canned.—Crush and stem, bulk-heat to 160° F, press, bulk-heat to temperature higher than final pasteurizing temperature, fill into 10-gallon-slip-cover enameled tins, freeze (to detartrate), thaw, filter, blend, bulk heat to 150° F, can in berry enamel-lined cans, seal, pasteurize, cool.

APRICOT

Canned.—Wash, steam, pulp and strain, add sugar or sirup, bulk-heat to 160° F, can, seal, pasteurize, cool.

PRUNE

Packed in Glass.—Screen to remove debris, extract two or three times with boiling water, filter the extract, pass the extracted prunes through a pulper to separate pits, filter the pulp and combine filtrate with filtered extracted juice, adjust to 20° Balling, concentrating in steam-jacketed kettle if necessary, bring to 185° F, fill hot, seal, pasteurize, and cool.

Canned.—As above.

ACKNOWLEDGMENTS

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FIRMS SUPPLYING FRUIT-JUICE AND BEVERAGE EQUIPMENT

For the convenience of those interested in the preparation of fruit juices or beverages from fruit juices the following partial list of firms is given:

General Equipment

Food Machinery Corporation, 70 Pine Street, San Francisco, Calif.
Hydraulic Press Mfg. Co., Mt. Gilead, Ohio.

Crushers, Presses, and Filters

American Seitz Filter Corporation, 667 Howard Street, San Francisco, Calif.
American Utensil Co., 466 West Superior Street, Chicago, Ill.
Brown Citrus Machinery Co., Los Angeles, Calif.
S. F. Bowser and Co., 1310 Creighton Avenue, Fort Wayne, Ind.
California Press Mfg. Co., 1800 Folsom Street, San Francisco, Calif.
Cellulo Filter Co., Sandusky, Ohio.
Ertel Engineering Corp., 120 East 16th Street, New York City, N. Y.
Hydraulic Press Mfg. Co., Mt. Gilead, Ohio.
Karl Kieffer Mfg. Co., Cincinnati, Ohio.
The Oscar Krenz Copper and Brass Works, 612 Bryant Street, San Francisco, Calif.
T. Shriver & Co., Harrison, N. J.
D. R. Sperry and Co., Merchants Exchange Bldg., San Francisco, Calif.
Watkins Fruit Machinery Co., 5815 3rd Street, San Francisco, Calif.
West Coast Machinery Co., 3238 17th Street, San Francisco, Calif.

Glass-enameled Equipment

The Glasscote Co., Euclid (Cleveland), Ohio.
Pfaudler Co., 122 New Montgomery Street, San Francisco, Calif.

Glass Manufacturers

Owens-Illinois Pacific Coast Co., 15th and Folsom Streets, San Francisco, Calif.

Filter Aids

The Dicalite Co., 756 South Broadway, Los Angeles, Calif.
Johns-Manville Sales Corp., 159 New Montgomery Street, San Francisco, Calif.

Bottling Machinery

Karl Kieffer Mfg. Co., Cincinnati, Ohio.
Liquid Carbonic Corp., 3100 South Kedjie Avenue, Chicago, Ill.
U. S. Bottlers Machinery Co., 4015 North Rockwell Street, Chicago, Ill.

Bottle Closures

Crown Cork and Seal Co., 1508 Barclay Street, Baltimore, Md.
Western Stopper Company, Inc., Western Division Crown Cork and Seal Co., 25th and Potrero Streets, San Francisco, Calif.
White Cap Co., 465 California Street, San Francisco, Calif.

Cans

American Can Co., 111 Sutter Street, San Francisco, Calif.
Continental Can Co., 57th Avenue and Russet, Oakland, Calif.
Pacific Can Co., 290 Division Street, San Francisco, Calif.

Pasteurizers

Cherry-Burrell Corp., 88 Clay Street, San Francisco, Calif.
Hydraulic Press Mfg. Co., Mt. Gilead, Ohio.
Jensen Creamery Machinery Co., 5305 Horton Street, Oakland, Calif.
The Oscar Krenz Copper and Brass Works, 612 Bryant Street, San Francisco, Calif.
Oakland Copper and Brass Works, 6th and Kirkham Streets, Oakland.

Vacuum Pans

Bradford Metal Co., Los Angeles, Calif.
Oakland Copper and Brass Works, 1346 7th Street, Oakland, Calif.
Pfaudler Co., 122 New Montgomery Street, San Francisco, Calif.
Zaremba Co., 506 Crosby Bldg., Buffalo, N. Y.

Soda Fountain and Bottlers' Supplies

L. H. Butcher Co., 15th and Vermont Streets, San Francisco, Calif.
Eng-Skell Co., 1035 Howard Street, San Francisco, Calif.
Lyons-Magnus, Inc., 2545 16th Street, San Francisco, Calif.
John Mulhern Co., 182 2nd Street, San Francisco, Calif.
Southern California Supply Co., 815 East 3rd Street, Los Angeles, Calif.

Clarifying Enzymes

Röhm and Haas Company, 222 West Washington Square, Philadelphia, Pa.
Takamine Laboratory, Incorporated, Clifton, N. J.

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